TECHNICAL BULLETIN NO. 38 DECEMBER, 1917

MICHIGAN AGRICULTURAL COLLEGE

EXPERIMENT STATION

IMPERIAL BUREAU
28 JUN. 1921
OF MYCOLOGY

BOTANICAL SECTION

EXPERIMENTS ON THE CONTROL OF BEAN ANTHRACNOSE AND BEAN BLIGHT

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EAST LANSING, MICHIGAN
1917

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INTRODUCTION.

The common field and garden beans are known technically as Phaseolus vulgaris, and the Lima bean as Phaseolus lunatus. Field beans are generally divided for commercial purposes into three types, viz., kidney, marrow, and pea beans. For the most part the beans grown commercially in Michigan are the kidney and white pea beans. There is, however, quite an acreage devoted to garden and lima beans, used in the seed trade or for canning purposes. Our work has had to do chiefly with the white pea or navy beans.

ECONOMIC IMPORTANCE OF THE BEAN INDUSTRY.

For the decade ending 1915 on the average Michigan ranks first in the production of dry edible beans, followed in order by California and New York. Something of the extent and economic importance of the crop may be gathered when one considers the fact that during this period this state produced about 70% of the entire output of dry edible beans in the United States. During the period 1905-15* the average acreage was 407,233, producing an average crop of 5,186,800 bushels. Every county, with the exception of five in the Upper Peninsula, grows some field beans. The fourteen principal bean growing counties produce practically as many field beans as the remaining 70 counties of the state. These counties with the acreage planted to beans in 1916 are given as follows:

TABLE 1.*—AVERAGE OF BEANS IN 1916.

Bay	2,855	Muskegon	802
Gratiot	21,261	Newaygo	5,087
Huron	29,025	Oceana	6,898
Isabella	27,665	Saginaw	30,668
Mecosta	8,611	Sanilac	18,655
Midland	15,962	Tuscola	38,300
Montcalm	12,962	Kent	14,012

*Data compiled from Michigan Crop Report, July, 1916.

It is a significant fact that the yield of beans per acre dropped from 15 bushels in 1905 to 11.25 bushels in 1914.

TABLE 2.—ACREAGE AND YIELD OF BEANS FOR THE YEARS FROM 1905 TO 1914.*

Year.	Total yield, bushels.	Total acreage.	Yield per acre, bushels.
1905	5,153,940	343,590	15
1906	5,158,160	368,440	14
1907	4,829,032	371,464	13
1908	4,301,544	358,462	12
1909	6,175,000	475,000	13
1910	6,113,250	470,250	13
1911	5,366,296	438,858	12
1912	5,268,631	408,007	12.9
1913	4,932,621	424,230	11.6
1914	4,669,514	414,035	11.3
Ten year average	5,186,798	404,425	12.8

*Data compiled from the Michigan Crop Report, 1905-1914.

The crop during these years was not seriously affected by weather conditions.

Two factors of the utmost importance in the growing of beans are bean diseases and weather conditions. Under ordinary conditions the ill effects of the weather are not very noticeable, but in a season such as that of 1915 they become extremely serious. The relation of weather conditions to bean diseases will be discussed subsequently. There are two diseases which cause serious damage to the bean crop. These are the bean anthracnose and the bean blight. Each will be discussed separately.

BEAN ANTHRACNOSE.

NAME.

The bean anthracnose is also commonly known to growers as pod spot, rust, or blight. However, since the bacterial blight is now recognized by the growers, the name blight is not frequently employed for the disease under discussion. The misnomer, rust, is used far less frequently since Michigan growers have come to recognize the signs of the anthracnose and the true rust.

HISTORICAL.

According to Saccardo and Magnus (1878), the disease was first found on garden beans in Poppelsdorf, Germany, by Lindemuth, in 1875. It was also reported as having been found in Italy at this time. Berkeley (1880) gave a description of the disease and mentions this as the first time he has seen it causing very severe damage to the pods and seeds within, although it was observed by him previous to this time, in a milder stage. Trelease (1885), reported finding specimens of bean anthracnose in 1882 in Wisconsin. Frank (1883) in Germany, reported serious damage to garden beans in 1882, caused by the bean anthracnose.

The first authentic specimens of bean anthracnose from Michigan seen by the writer, were collected by Dr. W. J. Beal in 1889, when the bean crop in the vicinity of Lansing was ruined. Although there are no earlier records of the disease in this state, it is quite evident that the bean anthracnose was present, probably several years previous to this date, without attracting any attention on account of losses to the crop.

Halsted, (1892) reported the disease from New Jersey, and Beach, (1892) reported it from New York. The disease was also reported in 1892 from North Carolina by McCarthy (1892), and from Maine by Harvey, (1893) Rolfs, (1896) in Florida; Bedford, (1889) in Canada; Sheldon, (1905) in West Virginia; Jarvis, (1908) in Connecticut; Barre, and Conradi in South Carolina, Pammel and King in Iowa, Wilcox and Temple in Nebraska, all reported the bean anthracnose as of more or less seriousness. Edgerton, (1910) reported the disease as doing serious damage in Louisiana. Selby, (1910) mentioned the disease as occurring in Ohio. A questionnaire sent to plant pathologists and botanists of western states brought out the fact that the bean anthracnose was present in varying degrees of severity in Washington, Oregon, California, Colorado, Montana, and Idaho, during 1914. Utah alone reported the absence of the disease. In the above mentioned states, the occurrence of the anthracnose was reported as rare or practically unknown. In addition to these states, the Plant Disease Survey* reports the occurrence of the disease in the following states: Kansas, Oklahoma, Texas, Arkansas, Missouri, Minnesota, Wisconsin, Illinois, Tennessee, Mississippi, Alabama, Georgia, Indiana, Virginia, Maryland, Pennsylvania, Delaware, Vermont, and Massachusetts.

SIGNS OF THE DISEASE.

A description of the signs of this disease at the different periods of growth can best be given by beginning with the disease on or in the seed.

On the Seed:

On the seed coat the bean anthracnose organism produces a distinct grayish or black blotch or spot with a more or less definite outline. Usually in light infection there is no marked discoloration of the cotyledon underneath the lighter colored grayish spot on the seed coat. With a deeper penetration of the fungus mycelium into the tissue of the cotyledon the spot or blotch on the seed coat assumes a darker color. Oftentimes the black definitely outlined spot on the seed coat surrounds a grayish center. Within this lighter central portion are the spore masses of the anthracnose organism.

On the Seed Leaves (Cotyledons):

When such disease discolored seeds are planted in soil containing a sufficient amount of moisture, the fungus develops further. The disease is then evident upon one or both cotyledons of the seedling. Here the organism produces a dark red or black spot often irregular in shape but with a definite outline. If the weather is damp, cool and misty, the pink spore masses of the fungus are formed within these cankers. Frequently under such conditions, the canker or lesion will spread from the cotyledons to the point of their attachment to the stem. This may result in a rotting-off of the upper portion of the stem.

*Through the kindness of Dr. G. R. Lyman of the Bureau of Plant Industry, Plant Disease Survey, these lists were furnished to the writer.

On the Seedling Stem:

As a rule the disease lesion of the cotyledons does not spread rapidly enough to cause the stem to rot off in a majority of cases, but remains as a source of infection to the more basal portion of the plant stem. Heavy dew, mist or rain may wash the spores of the fungus from this lesion down the stem. Here they lodge and, sending out a germ tube, penetrate into the tissue. This infection often results in the formation of circular spots or by their coalescence, elongated cankers. The mycelium may penetrate the stem tissue to such an extent as to cause the stem to rot off or weaken it to such an extent that it is broken over in cultivating or by a strong wind. Many of the blanks in the rows can be accounted for in this manner. The spores from lesions on the stem or cotyledons may be washed by rain down to the soil.

On the Leaves:

The infection is spread from the diseased stems and infected soil to the leaves of the plant. This is accomplished by the leaves brushing against the spore-bearing lesions on the stem during a rain or by the rain drops splashing the infected soil upon the lower leaves of the plant. Further leaf infection results when in wet weather, the upper leaves brush against the lower diseased ones. Cultivating beans when the leaves are wet with rain or dew will also spread the infection, not only from one leaf to another of the same plant, but may carry the fungus spores many feet down a row, inoculating every plant upon which they chance to lodge. The writer has frequently observed this method of spreading the infection. In one case under observation, a dog running across a bean field wet with dew, left a path almost across the entire field, which showed severe anthracnose infection six days afterward. The veins of the infected leaves are darkened and killed, this being more noticeable from the under side. (Plate I.)

On the Pods:

The anthracnose spores are washed from the diseased leaves or splashed from the soil to the young pods. In many cases the pedicel may be so affected as to cause the pod to shrivel or rot off. On the pod the disease lesion first appears as a dark red pin-point spot. This gradually enlarges and becomes circular having a diameter of from two to eight millimeters. The mature lesion has a dark red or black border, enclosing a rifted grayish central portion bearing the minute spore masses of the fungus. In severe infection the fungus mycelium penetrates the tissue of the pod producing the characteristic lesion upon the seed within, or entirely rotting the succulent seed. In case of light infection, the mycelium may not penetrate the pod. The writer's observations show that the mycelium does not penetrate the pod when it has begun to harden to an appreciable extent. Under favorable weather conditions this accounts for the light "pick" of very early maturing varieties of beans. (Plate II, figure 1 and Plate IV.)

Field Appearance:

If the early infection of the cotyledons and stems has been severe, the effects of the anthracnose are easily noticeable. Vacant spaces in the rows show that the seedlings have rotted off at the surface of the soil or that the seed has decayed before germination. Bare stalks indicate that the fungus infecting the cotyledons has spread to the growing tip causing it to rot off and preventing the production of leaves.

When the disease becomes severe after the first few leaves are produced, the fungus may attack the petioles, causing the leaves to wrinkle, yellow and finally drop. Severe stem lesions also cause the leaves to yellow because of the cutting off of the water supply. These leaves soon drop and the plants have a more or less stunted appearance.

However, if severe infection occurs after the plants are fully leafed, there may be no signs of the disease to the casual observer. The seriousness of the attack can only be ascertained by lifting up the vines and examining the undersides of the leaves and the pods for the disease lesions. This was the case during the 1915 season and as a result those who estimated the crop from observing the bean fields without entering them, were badly misled. From the appearance of the vines, the crop appeared to be above that of the ten year average. Upon close examination of the pods, it was seen that the bean crop was seriously damaged because the fungus had attacked the pedicels of the pods or the young pods themselves and prevented seed formation.

ECONOMIC IMPORTANCE.

During the early period of commercial bean growing in Michigan the nature of the losses to the bean crop were not understood. The cause of the spotting of the pods was, by some growers, ascribed to insects, while others thought it to be merely wet weather. The writer has been told by men who have engaged in bean growing for many years that during the earlier period of bean growing it was a general practice to plant "spotted" or "weathered" beans. This practice has been continued more or less generally until comparatively recent years, and even now is practiced to some extent.

The continued planting of seed affected with anthracnose, not knowing the nature of the trouble nor its serious consequences, has been a factor in the state wide epidemics of this disease in recent years.

From the reports of growers and bean jobbers of the state we find that for a period of three years from 1913 to 1916, the average pick per bushel of beans has been approximately 6 pounds. About 50% of this pick consists of diseased beans, the majority of which show severe anthracnose spotting. With the high prices paid for the crop during these years, this diseased portion of the pick represents an enormous financial loss to the grower. It is estimated that during 1914, the loss due to the anthracnose alone was no less than $1,500,000 and in 1915 approximately $3,000,000. The loss for the season of 1916 was very materially decreased, owing to the effects of the dry weather during the growing season, upon the development and spread of the anthracnose fungus. While Michigan suffers the greatest losses, on account of the larger acreage, some loss is sustained because of the attacks of either the anthracnose or bacterial blight in almost every state where beans are grown.

These losses caused by the above disease occur both in the growing crop and the mature seed. The growing plants so affected may be partially or wholly defoliated, causing a great decrease in the vigor of the plant and in its ability to set and mature a full number of pods. The seedlings may be so severely attacked that they rot off at the surface of the ground. In many cases seedlings so attacked are not entirely killed, but produce only small, stunted plants that set no pods. The pedicels of the green pods may be attacked causing the pod to shrivel or rot off and drop. The most obvious damage occurs when the young pods are attacked, the pathogene pene-

trating into the succulent seed, causing it to rot, or in cases of lighter infection, discoloring the seed.

Matured seeds so spotted are not salable as first grade beans, but must be picked from the cleaned product. The grower pays not only for the picking of these diseased beans, but every pound of such beans is deducted from the weight of the load at the rate per bushel paid for choice hand-picked beans.

ETIOLOGY.

Bean Anthracnose is caused by the parasitic fungus, *Colletotrichum lindemuthianum* (Sacc. and Magn.) Briosi and Cavara. The causal organism was first described by Saccardo and Magnus (1878) as *Gloeosporium lindemuthianum*. Scribner (1887) suggested, without confirming the fact, that if setae were present in the acervulus the genus name should be changed from Gloeosporium to Colletotrichum. Later in 1889 Briosi, proving the presence of setae with the conidiophores, changed the genus name to Colletotrichum. Shear and Wood (1907) from their experiments with different anthracnose organisms, renamed the bean anthracnose fungus *Glomerella lindemuthianum* (Sacc. and Magn.) Shear. More recent work by Edgerton (1915) shows the development of the perfect stage not sufficiently established to warrant the change in classification and the older name is generally retained.

PATHOGENICITY.

The organism causing the anthracnose of beans was readily isolated from the affected cotyledons of sterilized germinated seeds. Poured plates of cornmeal agar were made, and plants inoculated with spores obtained from sub-cultures of these plates. In every case inoculations were made by spraying the spore suspension upon the leaves and stems of the young plants. Re-isolations were made from the cankers produced on the stems of the plants grown under bell jars. Inoculation with spores from sub-cultures of the re-isolation also produced the typical leaf and stem infections.

The incubation period varies from three and one-half to six days, according to the amount of moisture present and the temperature. Frank states that infection was apparent 24 hours after inoculation, and Halsted obtained infection 36 hours after inoculation. Edgerton was not able to obtain characteristic infection sooner than four and a half days after inoculation.

MORPHOLOGY.

The Spore:

The hyaline spores at first are one-celled, but later, divided by a single septum. They are surrounded by a mucilaginous envelope. In mass, they are at first pink, later becoming more or less creamy. They are usually kidney shaped, varying in width from 2.7 to 5.3 microns and in length from 10.6 to 20 microns. Germination takes place by the sending out of a hyaline germ tube from near the end of the spore. More than one tube may arise from the same spore. The appressoria when present are usually formed after the germ tube has grown a short distance. These bodies are not always present in culture media, altho frequently found in poured plate cultures of the fungus.

Mycelium:

At first the mycelium is non-septate and hyaline. With further growth, septation takes place, the hyphae enlarge and branch. In culture, the mycelial growth is at first aerial and white but very soon turns brownish or black, and is scarcely noticeable upon the medium. In liquid media, the mycelium develops aerially in abundance and the growth remains white much longer than on agar. In several cases the white mycelium penetrated to the bottom of the culture flask after forming a surface mat.

Pycnidia:

In cornmeal agar cultures where the evaporation of water was almost eliminated and a large air space was present in the flasks pycnidia developed abundantly. Edgerton describes pycnidium formation within the seed but the writer has not observed these fruiting bodies altho they undoubtedly exist.

THERMAL RELATIONS OF THE FUNGUS.

Colletotrichum lindemuthianum is more sensitive to high temperatures than many of the closely related organisms causing similar diseases of other hosts. Edgerton (1915) has thoroly worked out the relative thermal death points of a number of such organisms in culture. On this basis he finds that the bean anthracnose fungus is readily separated from the other pathogenes studied. From his data it is seen that the mean temperature maintained thru the growing season in this state is very suitable for the growth and development of this fungus.

The optimum temperature for the growth of *Colletotrichum lindemuthianum* was found to be from 21° to 23° C. Growers in Louisiana utilize this low temperature requirement of the fungus in growing their seed beans. Since the fungus cannot withstand high temperatures, the beans for the seed crop are planted during the hot weather of the fall, and the temperature controls the anthracnose. Owing to the short season in the northern bean growing states such a practice is not possible.

Thermal relations of the old mycelium:

In order to find the effect of wet heat upon the mycelium of *Colletotrichum lindemuthianum*, the following experiment was performed:

Test tubes of thin glass containing 10 cc. of Coons' synthetic solution* were inoculated with bits of black mycelium from a pure, single-colony culture of the bean anthracnose fungus. These cultures were allowed to grow at room temperature for 70 days. These test tube cultures were then immersed in a constant temperature water bath for 10 minutes at different temperatures. After removing from the water bath the cultures were allowed to cool gradually at room temperature. Three poured plates of cornmeal agar were made from each culture. The following temperatures were employed in the experiment, with the results as tabulated:

*Coons, G. H. Factors involved in the growth and the pycnidium formation of Plenodomus fuscomaculans. In Jour. Agr. Res. 5:713-769. 1916. p. 752.

TABLE 3—THERMAL RELATION OF OLD MYCELIUM

Temperature.	Plates poured.	Growth in plates.
35°	1	Heavy black mat.
	2	Heavy black mat.
	3	Heavy black mat.
40°	1	Heavy black mat.
	2	Heavy black mat.
	3	Heavy black mat.
45°	1	Good. White layer.
	2	Good. White layer.
	3	Good. White layer.
50°	1	Fair. White layer.
	2	Slight. White layer.
	3	Fair. White layer.
55°	1	Fair. Black layer.
	2	Fair. Black layer.
	3	Fair. Black layer.
60°	1	Very slight. Black layer.
	2	Very slight. Black layer.
	3	Very slight. Black layer
65°	1	Good. Black layer.
	2	Good. Black layer.
	3	Good. Black layer.

In every case pure cultures were obtained from the poured plates.

Thermal Death-point of Spores:

The thermal death-point of spores of *Colletotrichum lindemuthianum* was determined in a similar manner. Soyka dishes containing 15 cc. of Coons' synthetic solution were inoculated with bits of mycelium of the fungus. After 75 days' growth the fungus had produced spores in abundance. The liquid culture was then filtered thru a sterile pipette filter of glass wool and absorbent cotton into a sterile flask. Sterile glass tubing with a bore of 5 mm. was pulled out into a long capillary tube having a bore of about 1 mm. A portion of the spores suspension was taken up and the tube sealed with a flame. Sections of this tube were made by fusing it with a micro-burner. These sections containing the spores were immersed for 10 minutes at various temperatures in the water bath. After immersion the sections were cooled in running tap water. In making dilution plates from the contents of these tubes, they were first sterilized in bi-chloride of mercury solution. One end of the tube was broken with flamed forceps. This end of the tube was introduced into the mouth of a test tube of melted agar (42° C.) and a flame applied to the other end of the tube. Steam was generated within the tube and forced the spore suspension into the tube of medium. Three dilution plates were made for each temperature of immersion. The first immersion was made at 37.5° and the last at 60°. Good growth took place in the plates from the suspension immersed at 45°, while in those from the suspension immersed at 48° there was no growth. The thermal death-point of the spores lies therefore between 45 and 48 degrees Centigrade.

Thermal Death-point of Young Mycelium:

Test tubes of sterile distilled water were inoculated with single colonies from a liquid culture of the bean anthracnose fungus, 29 days old. These tubes were immersed in a constant temperature water bath at various tem-

peratures for ten minutes. Immersions were made at temperatures ranging from 40° to 60° C., with intervals of 2.5 degrees. The tubes after immersion were allowed to cool at room temperature. Two poured plates were made from the colonies in each of the treated tubes. There was no checking of growth apparent in the plates at temperatures from 40° to 50° C., but at 52.5° C., there was no growth in the cultures. The thermal death-point, then, of the young mycelium lies between 50° and 52.5° C.

RELATION OF WEATHER CONDITIONS TO THE ANTHRACNOSE.

Temperature, moisture in the soil, rain, and dew play an important role in the occurrence, spread, and severity of the bean anthracnose. The effect of a hot dry season on the disease was well demonstrated during the summer of 1916. Low temperature is necessary for the optimum development of the fungus. Moisture in the soil is necessary to the growth of the pathogene upon or in the seed beans, and its spread to the plumule and radicle. After the cotyledons have been pushed above the surface of the ground, rain or dew are required to furnish moisture sufficient for the growth of the fungus and the production of spores as well as to wash the spores from one part of the plant to another.

It has been our observation that beans grown on low ground or poorly drained soil are usually more severely affected with the anthracnose than those grown on higher or well-drained soil. Because of the greater amount of moisture retained by the soil in low places and by the poorly drained soils, the atmosphere immediately surrounding the plants has a greater humidity and a lower temperature. Both of these factors are conducive to the growth and spore production of the fungus.

Under Michigan conditions at least, the mean humidity is not of so great importance in the growth and spread of the anthracnose organism as are temperature, rainfall, and percentage of sunshine. Climatological data covering the period 1913 to 1916, inclusive, bear out the above statement.

In order to compare the effects of weather conditions upon the development of the anthracnose, it is necessary to determine a standard of infection which remains constant or approximately so throughout a period of years. For this purpose, the average pick per bushel of diseased beans, on a commercial basis, has been adopted. The estimated pickage of diseased beans was furnished by the Michigan Bean Jobbers' Association, in various localities of the state. The condition of the bean crop of the state as a whole is well represented by this average pick per bushel. The pick per bushel represents the amount of unsalable beans taken out of a bushel of beans to prepare it for the grade of "choice hand-picked." This grade of beans, according to the rulings of the Association, must not contain in a bushel more than 1.5% of discolored or split beans, and the finished product is carefully inspected by the foreman to see that it is up to the standard of the grades.

It is not to be inferred that this commercial pick represents the actual amount of diseased seed in a bushel of beans. The average pick per bushel is only a relative value. Under normal conditions about 50% of the pick is made up of diseased beans. Of this amount about 70% are affected with anthracnose and 30% with the blight.

These data* are as follows:

TABLE 4—AMOUNT OF DISEASE IN RELATION TO WEATHER CONDITIONS.

Year.	Month.	Mean temperature.	Total precipitation.	Number rainy days.	Percentage of sunshine.	Mean relative humidity.	Average pick per bushel.
1913	June	68	1.01	6	83	67	3 lbs.
	July	71	2.85	10	72	70	
	August	69	5.60	14	65	60	
1914	June	66	4.11	10	70	69	4 lbs.
	July	71	1.65	5	70	74	
	August	69	3.33	12	68	79	
1915	June	61	3.96	15	54	76	10 lbs.
	July	68	5.17	16	54	79	
	August	63	4.63	13	56	85	
1916	June	61	5.39	18	66	76	2 lbs.†
	July	76	0.09	2	91	70	
	August	71	1.58	8	79	77	

*The climatological data were furnished by Mr. D. A. Seeley, local forecaster of the U. S. Weather Bureau, East Lansing.

†The pick of the 1916 crop was made up very largely of frosted beans with 10-25% of blighted beans. The quantity of beans affected with anthracnose was too small to permit an estimate of the percentage of the pick so affected.

BEAN BLIGHT.

NAME.

Bacterial blight of beans is commonly given the name of "bean blight" or merely "blight." By some growers it has been called rust, due to the rusty appearance of the flecks or blotches, caused by the pathogene upon pods and seeds. Within the last three years, however, this latter name has almost disappeared from common usage of the grower.

HISTORICAL.

The presence of the bacterial blight upon beans was first reported from New York by Beach (1892). Halsted (1892) the same year, described the disease from New Jersey, but stated that it had been known in the state as early as 1886, although not previously described. The first authentic specimens of bean blight in Michigan seen by the writer were collected on variety plats at the Agricultural College by Dr. C. F. Wheeler, in 1897. Dr. E. F. Smith described the disease in 1897. In 1896, Delacroix (1899) recognized bean blight as the "grease disease" occurring on varieties of garden beans grown on the outskirts of Paris, France. This author gives a description of the signs of the disease on the host and the characteristic appearance of the affected field. Edgerton (1911) reported the blight as a serious disease of Louisiana. Since its discovery the bacterial blight has spread to practically every state where beans are grown on a commercial scale and bids fair to rival the anthracnose disease in seriousness. It has been found on samples of beans from the principal western bean-growing states, California, Idaho, Washington, Arizona, Montana. Marked discolorations, characteristic of the blight, have been found in abundance upon South American white beans shipped to this country from Brazil. The

Plant Disease Survey reports the occurrence of bean blight in the following additional states: Massachusetts, Connecticut, Pennsylvania, Maryland, Delaware, Ohio, Virginia, North Carolina, Indiana, Alabama, Mississippi, Texas, Oklahoma, Colorado, North Dakota, South Dakota, Nebraska, Minnesota and Wisconsin.

Until recent years, this disease has been largely mistaken for frost injury by Michigan growers and elevator men. Since in the case of slight infection, there was no appreciable effect upon the germination of the seed, such blighted beans were planted as a general practice, without realization of the serious effect upon the succeeding bean crops.

SIGNS OF THE DISEASE.

On the Seed:

In case of light attack, light yellow blotches without definite margins are produced on the seeds, but in cases of severe infection the coloring is deeper and the whole seed may be involved. Infected seed may also be smaller in size and more or less shriveled. The blight infected seed is not to be confused with seed injured by frost. Frosted seed are of a more greenish-yellow or grayish-green color as compared with blighted seed.

On Seed Leaves:

When such infected seeds are planted and the seedlings appear above the surface of the ground, infected areas may be seen on the cotyledons or seed leaves. Here they are first seen as amber-colored spots or blotches without a well-defined margin. These may enlarge until one or both of the seed leaves are discolored. In some cases the cotyledons are smeared with the yellow, bacterial slime.

On the Stem:

The bacteria washed down from the cotyledons produce reddish brown cankers on the stem. These lesions are not so deep as those of the bean anthracnose, nor are they so dark in color. These cankers do not have the definite margins, characteristic of the anthracnose spots.

On the Leaves:

The first appearance of the disease upon the leaves is as small, irregular, water-soaked areas. These areas are more or less puffed up like blisters and may spread until the entire margin or leaf is involved. Later this water-soaked area dries out and turns brown with the collapse of the leaf tissue. The dead areas frequently fall out or the whole leaf is shed. Yellow bacterial masses are frequently scattered over the diseased portion of the leaf.

On the Pods:

The diseased spots start as small, slightly raised, watery pustules on the pod. These increase in circumference, assuming an amber color. It is not uncommon to see an amber-colored outer area surrounding a slightly raised inner dark green portion. Infection may appear as very small amber blotches, scarcely noticeable on the pod. In the centers of old spots the yellow crusts of bacteria are found. We have noticed that infection is most severe along the hinge of the pod and upon the side exposed to the sunlight. When the bacteria penetrate the pod, yellowed or shriveled seeds may be produced.

Field Appearance:

When blighted seeds are planted and wet weather is abundant, they may fail to germinate, or seedlings with severely infected seed leaves are produced. This also accounts to a certain extent for skips in the rows.

In case of severe infection, the field looks as if the plants had been drenched with hot grease, as described in France. The leaves show severe browning or the plants may be completely defoliated. The plants rapidly produce new leaves and blossoming is profuse and irregular. This causes an uneven setting of the pods which cease to fill out or ripen unevenly.

ECONOMIC IMPORTANCE.

Since this disease is so closely associated with the bean anthracnose, it is difficult to secure reliable figures expressing the damage to the crop by the blight. However, it is probable that fully 30% of the diseased beans in the pickage are infected with the blight.

ETIOLOGY.

Bacterial bean blight is caused by the organism *Bacterium phaseoli* Erwin F. Smith. The causal organism was thoroly studied by Smith (1897) and given the name *Bacillus phaseoli*. Later this genus name was replaced by that of Pseudomonas. The genus name Bacterium Cohn emend. was substituted for that of Pseudomonas Migula.

MORPHOLOGY AND PHYSIOLOGY.

Bacterium phaseoli is a motile rod with rounded ends, and a single polar flagellum. On potato plugs, carrot plugs, turnip plugs, bean plugs, and standard nutrient agar, it produces a yellow, viscid growth. In beef bouillon and Uschinsky's solution, growth is very slow. Gelatin is slowly liquified; no acid reaction is evident in litmus milk; no gas is formed; on potato cylinders growth at first is a bright yellow, changing with age to a yellowish brown color, as the potato is disintegrated. The thermal death-point of *Bacterium phaseoli* as reported by Smith is 49.5° C.

RELATION OF WEATHER CONDITIONS TO THE BLIGHT.

In general it may be said that weather conditions favoring the development of the bean anthracnose are also favorable for the growth and spread of bacterial blight. There is this difference, however: the bacterial blight is much more severe during a hot dry season than the anthracnose. This is due chiefly to two causes. *Bacterium phaseoli* is more resistant to heat than the anthracnose fungus. Also the blight bacteria are not so dependent upon moisture for their dissemination as are the spores of the fungus pathogene. Moisture at planting time is essential for the growth of the bacteria upon or in the infected bean seed, and for their spread from the cotyledons to the stems and leaves of the seedlings. In the later stages of the disease, after the leaves have become infected, moisture is not necessary for further dissemination of the blight bacteria. Once the infected portion of the leaf becomes broken and falls away, the bacteria are taken up by the wind and carried to other parts of the field.

DISSEMINATION OF BACTERIUM PHASEOLI.

The rapid spread of bean blight through the field even under dry weather conditions has led us to look for the agents of dissemination. Bean seedlings showing no trace of infection from the blight organism were covered with cloth cages. The plants caged were selected from different portions of the field. There were eight cages, each containing from ten to fifteen plants. These cages were made from unbleached bunting of such a weave as to insure normal growth of the plants without admitting insects. The cages were not disturbed until the beans were mature and the experiment terminated.

It was found in all cases that the caged plants were much less affected with the blight than the uncaged plants in the remainder of the plot.

Since no insects had access to the caged plants, these agents of dissemination were eliminated. The close weave of the cloth covering would permit the entrance of only the smallest dust particles to the plants. For the same reason rain-splashed soil, excepting very small particles could not pass through the cloth covering of the cages. The results obtained tend to show that the bean blight organism is more likely carried by the wind. It is also probable that individual diseased plants serve as the infection centers from which the bacteria in minute water drops are carried by the wind to other parts of the field. During the early stages of infection in the field, it has been frequently observed that the infection will spread from a single diseased plant to the adjacent plants on the same row and plants opposite it in parallel rows.

OVER-WINTERING OF THE ANTHRACNOSE AND BLIGHT ORGANISMS.

It is a well known fact established by Halsted (1891), Gain (1898), Beach (1892), and later investigators, that *Colletotrichum lindemuthianum* and *Bacterium phaseoli* live over winter in the infected bean seed. Different investigators have also suggested that these pathogenes may live through the winter in the soil on diseased vines or trash from the bean field. Experiments under controlled conditions to prove these statements have, however, been lacking. Halsted (1902) states, "It was shown that old spotted pods when used as a mulch greatly increased the disease (anthracnose) upon the area thus covered." No report is made of experiments showing that the fungus winters over in the soil. Gain (1898) in his experiments shows that the soil in which diseased seeds were planted, became infested with the anthracnose fungus, transmitting the disease to beans subsequently planted in the diseased soil. McCready (1911) in his observations on the bean blight says, "The disease is carried over from year to year in the seed from a diseased crop, in the soil on which a diseased crop has been grown or straw from infected fields in bedding or manure." This writer does not mention any experiments under controlled conditions to prove the points which he made.

In our own field work it has been observed in several cases, that where beans had been planted in fields immediately following a diseased crop, the

second crop, from cleaner seed than the first, was more severely affected by both the anthracnose and the blight. It has also been observed that where a portion of a field was fertilized with bean straw manure, and beans planted on it, the crop from this portion of the field was much more affected with these diseases than the crop from the unfertilized portion. The question as to whether or not the anthracnose and blight organisms live over winter on diseased bean-straw manure or in the soil of the field from which a diseased crop has been harvested, led to the following experiments:

OVER-WINTERING ON DISEASED BEAN STRAW.

Two series of experiments were performed with a view to finding whethe or not these organisms lived over in the soil or on diseased bean trash. Four large pots, 12 inches in diameter, were sterilized inside with $HgCl_2$, 1-1000, and filled with soil which had been sterilized in bags in the autoclave for two hours under 20 pounds pressure. Into the soil in pot I were thoroughly mixed with a sterilized trowel, finely chopped bean vines and pods badly infected with both the anthracnose and blight organisms. The soil in pot II was inoculated with a liquid culture of *Bacterium phaseoli* of proved virulence. Likewise pot III was inoculated with a liquid culture of *Colletotrichum lindemuthianum,* which was also virulent. Pot IV was used as a check and the sterile soil left uninoculated. The four pots of soil were left in the greenhouse three days and then set outside on September 30th, 1914, to winter over. On June 4th, 1915, the soil in each pot was transferred to eight six-inch sterilized pots. Four disease-free beans, grown in the greenhouse, were planted in each pot on June 10th, watered with sterile, distilled water and left outside the greenhouse. There were no beans growing closer than a quarter of a mile, and this small plot was behind one of the buildings, entirely separated from the plots. When the seedlings came up, there was no sign of either disease on the cotyledons or stems. There followed in the latter part of June two days of heavy rains and muggy weather. On examining the plants on July 13th, anthracnose infection was found on the plants in Series I and III. The infected leaves were at once pulled off to avoid spreading the infection, although no spores were found in the lesions at the time. The plants were again examined July 19th and although more anthracnose infections were found in these series, no evidences of blight were seen in the plants of series II and IV. Owing to extensive field trips during the summer the plants were not again examined until Sept. 10th, at which time all the plants of the four series were badly infected with the blight. It would seem from these results that the anthracnose infection started from the soil in the pots of series I and series III and that blight infection came from the soil in the pots of series II and IV. The fact that the beginning of the blight infection was not observed admits of some doubt as to the actual source. But the infection must have come from the inoculated soil or the bacteria were carried by the wind or insects from the bean plots previously mentioned. The latter source of infection seems hardly probable. The data obtained are given in the following table:

TABLE 5—OVERWINTERING OF ANTHRACNOSE AND BLIGHT, 1914-1915.

SERIES I. STERILE SOIL MIXED WITH VINES AND PLANTS INFECTED WITH BLIGHT AND ANTHRACNOSE.

Pot No.	Plants.	Diseased plants.											
		An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.
1	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
2	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
3	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
4	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
5	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
6	4	0	0	6/16	0	0	7/13	3	0	7/19	0	4	9/10
7	4	0	0	6/16	0	0	7/13	1	0	7/19	0	4	9/10
8	4	0	0	6/16	1	0	7/13	4	0	7/19	0	4	9/10

SERIES II. STERILE SOIL INOCULATED WITH BACTERIUM PHASEOLI.

Pot No.	Plants.	Diseased plants.											
		An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.
1	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
2	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
3	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
4	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
5	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
6	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
7	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
8	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10

SERIES III. STERILE SOIL INOCULATED WITH COLLETOTRICHUM LINDEMUTHIANUM.

Pot No.	Plants.	Diseased plants.											
		An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.
1	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
2	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
3	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
4	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
5	4	0	0	6/16	0	0	7/13	1	0	7/19	0	4	9/10
6	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
7	4	0	0	6/16	0	0	7/13	1	0	7/19	0	4	9/10
8	4	0	0	6/16	1	0	7/13	0	0	7/19	0	4	9/10

TABLE 5—*Continued.*

SERIES IV. STERILE SOIL NOT MULCHED OR INOCULATED. CHECK.

Pot No.	Plants.	Diseased plants.											
		An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.	An.	Bl.	Date.
1.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
2.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
3.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
4.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
5.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
6.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
7.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10
8.....	4	0	0	6/16	0	0	7/13	0	0	7/19	0	4	9/10

This experiment was repeated in 1915-1916. Four series of eight pots each were employed. Sterile soil to be used in series I was inoculated with liquid cultures of *Colletotrichum lindemuthianum* and after 18 days was set outside the greenhouse to winter over. On December 30, 1915, sterile soil to be used in series II was thoroughly soaked with a liquid culture of *Bacterium phaseoli* and on January 1, 1916, it was set outside. A pot of sterile soil to be used in series III was thoroughly mixed with bean pods, stems, leaves, and dust from the diseased field of 1914, and after wetting down, set outside to winter over. Likewise, a pot of sterile soil to be used in series IV was thoroughly mixed with bean mulch from our plots of 1915. The 1914 mulch had been kept a year in the dry, warm basement before mixing with the sterile soil. A check of sterile soil was also prepared and left outside all winter.

On June 2, 1916, the soil from each of these pots was transferred respectively to eight sterile six-inch pots. Two disease-free seeds were planted in each and the soil moistened with sterile distilled water. These pots, arranged two rows to a series, were sunk in the soil. At this time, the soil was very wet from recent heavy rains and the soil in the pots became almost saturated. However, the seeds germinated fairly well and the plants produced a vigorous growth. Grass was allowed to grow in between the pots and at the conclusion of the experiment, it was as high as the bean plants. This provided a natural barrier to the dissemination of the spores or bacteria of the causal organisms. It also furnished shade for the plants, thus creating possibly more favorable conditions for infection. The plants were examined from time to time, but no record was made until the last examination on September 18th. This examination should have been made earlier when the plants were in full foliage, but owing to field trips it was impossible. The following table shows the results of this experiment:

TABLE 6—OVERWINTERING OF ANTHRACNOSE AND BLIGHT, 1915-1916.

SERIES I. SOIL INOCULATED WITH COLLETOTRICHUM LINDEMUTHIANUM.

Pot No.	Plants.	Anthracnose.			Blight.			Remarks.
		Leaf inf.	Stem inf.	Pod inf.	Leaf inf.	Stem inf.	Pod inf.	
1	1	0	0	0	0	0	0	
2	1	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	Plants failed to grow.
4	0	0	0	0	0	0	0	Plants failed to grow.
5	1	0	0	0	0	0	0	
6	1	0	0	0	0	0	0	
7	2	0	0	0	0	0	0	
8	1	0	0	0	0	0	0	

SERIES II. SOIL INOCULATED WITH BACTERIUM PHASEOLI.

Pot No.	Plants.	Anthracnose.			Blight.			Remarks.
		Leaf inf.	Stem inf.	Pod inf.	Leaf inf.	Stem inf.	Pod inf.	
1	2	0	0	0	0	2	0	All leaves killed by extreme heat.
2	1	0	0	0	7	3	0	Cankers at nodes of stem and branches.
3	1	0	0	0	0	1	1	
4	1	0	0	0	0	2	3	
5	2	0	0	0	0	0	1	
6	2	0	0	0	0	5	0	
7	2	0	0	0	0	0	0	
8	1	0	0	0	0	1	0	

SERIES III. SOIL INOCULATED WITH DISEASED BEAN TRASH FROM PLATS OF 1914.

Pot No.	Plants.	Anthracnose.			Blight.			Remarks.
		Leaf inf.	Stem inf.	Pod inf.	Leaf inf.	Stem inf.	Pod inf.	
		Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	
1	1	0	0	0	0	1	1	
2	2	0	0	0	0	3	1	
3	1	0	0	0	0	1	0	Leaves all killed.
4	2	3	0	0	4	6	0	
5	2	0	0	0	0	9	3	
6	1	0	0	0	3	9	0	
7	1	0	0	0	2	3	1	Two pods clean.
8	2	0	0	0	3	2	2	Three pods clean.

TABLE 6—*Continued.*

SERIES IV. SOIL INOCULATED WITH DISEASED BEAN TRASH FROM PLATS OF 1915.

Pot No.	Plants.	Anthracnose.			Blight.			Remarks.
		Leaf inf.	Stem inf.	Pod inf.	Leaf inf.	Stem inf.	Pod inf.	
		Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	
1	0	0	0	0	0	0	0	
2	2	0	0	0	3	2	3	
3	2	0	0	0	4	3	5	
4	0	0	0	0	0	0	0	
5	2	2	0	0	0	5	0	
6	1	0	0	0	5	3	0	
7	2	0	0	0	9	11	3	
8	2	0	0	0	5	4	8	

SERIES V. CHECK.

Pot No.	Plants.	Anthracnose.			Blight.			Remarks.
		Leaf inf.	Stem inf.	Pod inf.	Leaf inf.	Stem inf.	Pod inf.	
		Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	Cankers.	
1	1	0	0	0	0	0	0	
2	1	0	0	0	0	0	0	
3	1	0	0	0	0	0	0	
4	1	0	0	0	0	1	0	
5	2	0	0	0	0	0	0	Dead.
6	1	0	0	0	0	0	0	Dead.
7	1	0	0	0	0	0	0	Dead.

The series of pots given in tables 5 and 6 were arranged in the same order in the field as in the tables. In the first experiment the pots were placed so close together that when the plants were full grown, the foliage came into contact. This may explain the wholesale blight infection in table 5 evident at the last examination, and these results should perhaps be thrown out. In both experiments only sufficient water was added to each pot at the time of planting to insure germination. When the pots in series I were set outside, the soil became dry. In this way infection of the plants was dependent upon the splashing of infected soil upon the stems and leaves. No evidence of infection was apparent upon the cotyledons of the seedlings. No infection resulted until after two days of heavy rain, when anthracnose spots were found upon the leaves of plants.

From the results of the first experiment, the writer is convinced that the bean anthracnose organism lives over winter in the soil, the chief source of infection being the diseased bean trash left upon the ground from one season to the next. These data also point to the fact that diseased bean trash is a greater source of infection than the presence of spores of the fungus in the soil.

Bean blight spreads rapidly thru a field under favorable conditions. It is

to be regretted that it was not possible to obtain a record of the date of the first appearance of blight infection in this experiment. But from the amount of infection upon the plants, practically every leaf and pod being blighted, it is evident that the infection started from the soil in the pots of series II, III and IV.

In comparison with the season of 1915, there was scarcely any rain in the season of 1916. This dearth of moisture naturally decreased the chance of infection from the soil. But in spite of such dry hot weather in the second experiment, infection of the leaves with the anthracnose resulted in two cases. With the exception of two cases, some part of every plant grown in soil inoculated with *Bacterium phaseoli* or blighted bean trash showed infection from the bacterial blight. It is to be expected that if these experiments had been carried on in the greenhouse under controlled conditions of temperature, humidity, and watering, the results would have been far more satisfactory.

From the data obtained from these two experiments, the writer is convinced that the causal organisms of both the anthracnose and the blight live over winter in the soil, on diseased bean trash, and as spores or bacteria in the soil, and are able to infect the crop of the next season.

IN MANURE.

It has been suggested by McCready (1911) that the bacteria of the bean blight live over in the soil, in bedding and manure. An experiment was performed to determine whether *Colletotrichum lindemuthianum* and *Bacterium phaseoli* could survive passage through the alimentary tract of cattle. A cow was stanchioned and fed badly diseased bean fodder and bran for 9 days. At the end of the ninth day, the feces were caught in a pail which had been sterilized by thoroughly washing in 1-1000 solution of mercuric chloride and boiling twice in sterile water for 30 minutes.

A portion of this manure was moistened with sterile distilled water. Twelve sterilized three inch pots were filled about two-thirds full of sterilized soil and then a layer of manure about one and one-half inches thick was added. The soil and manure were thoroughly mixed with a sterilized trowel. Two disease-free bean seeds grown in the greenhouse were planted in each of two pots of uninoculated sterilized soil as checks. The seeds were planted on January 8, 1915, and the experiment continued until February 2. The seedlings, and later the plants, were examined at intervals of five days. In no case was there any infection from either blight or anthracnose organisms.

TABLE 7.—RESULTS FROM SEEDLINGS GROWN IN SOIL MIXED WITH DUNG.

No. seedlings.	Treatment of soil.	Plants affected.	Time of	
			Planting.	Observation.
10	Mixed with dung	None	1/8/15	2/2/15
4	Sterilized	None	1/8/15	2/2/15

Further tests of the infectiousness of this manure were made by spraying upon healthy bean plants, a manure solution. This solution was made by

adding 50 grams of the manure to 200 cc. of sterile distilled water. It was then strained through sterile cheese cloth and sprayed upon the plants with an atomizer. Bell jars were then placed over the plants. The inoculations were made on December 2, 1914, upon plants three weeks old. On December 22nd the experiment was concluded as the incubation period of both organisms easily falls within this extent of time. No evidences were seen of infection from either *Colletotrichum lindemuthianum* or *Bacterium phaseoli*. The checks, consisting of two healthy plants in each of two pots and sprayed with sterile distilled water, remained free from the diseases. In like manner on December 21, healthy bean plants were sprayed with dung solution. The checks consisted of seven healthy plants, three of which were sprayed with sterile distilled water, and four with a culture of Bacterium phaseoli. The plants were covered with bell jars and examined each day until the experiment was terminated on January 10, 1916. No infection appeared upon the plants sprayed with dung solution or with sterile distilled water. One leaf of one plant sprayed with the bacterial culture showed unmistakeable signs of blight infection.

TABLE 8.—INOCULATIONS OF SEEDLINGS WITH DUNG SOLUTION.

No. seedlings.	Treatment of seedlings.	Plants affected.	Time of	
			Inoculation.	Observation.
8	Dung solution sprayed on leaves and stems	None	12/2/14	12/16/14
4	Sprayed with sterile water	None	12/2/14	12/16/14
16	Sprayed with dung solution	None	12/21/14	1/10/15
3	Sprayed with sterile water	None	12/21/14	1/10/15
4	Sprayed with culture of Bact. phaseoli	1	12/21/14	1/10/15

Twelve dilution plates, with standard nutrient agar were made from a manure solution. Dilution plates of *Bacterium phaseoli* and *Colletotrichum lindemuthianum* were also made. No bacterial or fungus colonies resembling those of *Bacterium phaseoli* and *Colletotrichum lindemuthianum* appeared. The pathogenicity of the bacteria and fungi found in the manure solution was not tested. From the examination, however, there was no doubt that the blight and anthracnose organisms were absent from these plates.

From the data obtained from these experiments it seems probable that these bean disease organisms do not survive passage through the alimentary tract of cattle. Although this is the case in the feces itself, there is still danger from using the manure from cattle fed with diseased bean fodder. Cattle, in feeding, nose the fodder out of the mangers. This is trampled under foot or used for bedding and later finds its way to the field as manure. Since the organisms do live over in the soil and on the diseased vines, pods and leaves, the manure becomes a source of infection to the bean crop planted upon soil so fertilized.

CONTROL MEASURES.

PREVIOUS WORK.

Since the anthracnose and blight have come to be recognized as serious diseases of the bean crop, a number of workers have tried or suggested various control measures for them. Halsted (1892) recommended soaking the seed in a solution of copper carbonate and ammonia for the control of the anthracnose. Edgerton (1910) as a result of his experiments suggests soaking the seed in hot water at 50° C. for ten minutes as a possible control measure.

Spraying the plants with Bordeaux mixture has been recommended by different authors as a control measure for anthracnose. Among these may be mentioned Halsted, McCarthy, Beach, and Fulton. Whetzel (1908), however, states that with the present machinery, spraying to control this disease is unsatisfactory. The latter with other workers recommends the planting of clean seed as the only safe method of getting rid of bean anthracnose. Barrus (1915) has found a variety of red kidney beans, which although not immune, is highly resistant to bean anthracnose. He found no variety of white pea beans which was resistant to either the anthracnose or the blight.

Edgerton found that the planting of home grown seed from the fall crop, grown under weather conditions which were unfavorable to the anthracnose fungus, or the use of Colorado seed materially decreased the disease. This author found that under Louisiana conditions mercuric chloride solution and benetol used for treating the seed, were effective to a certain extent in controlling the initial infection from the blight. Plants from the Colorado seed were more affected with the blight than the home-grown or Michigan seed. Most writers on the subject recommend the planting of clean seed as a control for the blight.

Barlow (1904) suggests that a possible control for the blight may be found in treating the seed with hot water or mercuric chloride solution.

STATEMENT OF THE PROBLEM.

The main problem in the investigation of the diseases, bean anthracnose and bean blight, has been to find a means of controlling these diseases either singly or together. The problem is rendered more complicated because of the fact that one disease is caused by a fungus while the other is of bacterial origin.

The fact that these diseases are of long standing and have become firmly established in every locality of the state where beans are grown, renders the problem more difficult of solution. In our work we have employed eradication, elimination, and protection methods of control. These experiments may be classified under the following headings: Spraying, seed treatments, separation of diseased and healthy seed, seed selection, pod selection, rogueing, growing disease-resistant varieties, disease-escaping varieties, native western beans, and western-grown Michigan beans.

SPRAYING.

During the seasons of 1912*, 1913, and 1914, spraying experiments were carried on for the control of the bean anthracnose and bean blight. Diseased seed was planted and spraying begun when the plants were about six inches high. Applications of the spray materials were made at frequent intervals until the plants were in blossom. Bordeaux mixture 4-4-50, and lime-sulphur 1-50 were employed in the tests. Spray materials were applied with a knapsack sprayer, care being taken to cover the entire plant. No exact determinations for the amount of disease upon the sprayed and unsprayed plants were made. It was very evident in all these cases, however, that the spraying was not an effective means of controlling either the blight or the anthracnose.

During the season of 1917 a fourth spraying experiment was undertaken. In this experiment the diseased beans were planted both in hills and in rows in order to obtain data on the best method of planting to avoid disease.

The beans were planted in two plats, each 60 feet wide and 100 feet long. The beans in one plat were planted in hills 28 inches apart each way, and in the other in rows 28 inches apart and six inches apart in the rows. Each plat was divided longitudinally, one-half being sprayed and the other half left as a control.

It was intended to spray the beans just as soon as the first true leaves began to show. Owing to very wet weather it was impossible to get into the field until the cotyledons had dropped and the first leaves were well developed. This lateness in the application of the first spray undoubtedly affected the results of the experiments.

Spraying was continued until the pods were formed; an application of Bordeaux 4-4-50 being made each week. In all seven applications were made, for the most part with a knapsack sprayer. At the end of the season the relative amounts of infection from both anthracnose and the blight were determined.

One hundred plants were pulled at random from each of the sprayed and control plats. These plants were then arranged in ten piles representing the relative percentages of infection ranging from 10 to 100. The following results were obtained:

TABLE 9.—RELATIVE PERCENTAGE OF BLIGHT INFECTION ON SPRAYED AND UNSPRAYED PLATS.

BEANS PLANTED IN HILLS.

Sprayed.		Unsprayed.	
Percentage infection.	Number of plants.	Percentage infection.	Number of plants.
10	10	10	4
20	4	20	14
30	5	30	15
40	4	40	4
50	16	50	15
60	18	60	6
70	12	70	8
80	10	80	2
90	12	90	2
100	9	100	0

Average percentage of infection: Sprayed, 60.1; unsprayed, 28.4.

*The spraying experiments during the seasons of 1912 and 1913 were conducted by Dr. G. H. Coons.

TABLE 10.—RELATIVE PERCENTAGE OF BLIGHT INFECTION ON SPRAYED AND UNSPRAYED PLATS.

BEANS PLANTED IN ROWS.

Sprayed.		Unsprayed.	
Percentage infection.	Number of plants.	Percentage infection.	Number of plants.
10	12	10	10
20	14	20	10
30	20	30	17
40	15	40	17
50	10	50	20
60	14	60	15
70	4	70	8
80	5	80	2
90	3	90	0
100	3	100	0

Average percentage of infection: Sprayed, 41.9; unsprayed, 41.1.

TABLE 11.—RELATIVE PERCENTAGE OF ANTHRACNOSE INFECTION ON SPRAYED AND UNSPRAYED PLATS.

BEANS PLANTED IN HILLS.

Sprayed.		Unsprayed.	
Percentage infection.	Number of plants.	Percentage infection.	Number of plants.
10	0	10	12
20	0	20	6
30	0	30	2
40	0	40	3
50	0	50	0
60	0	60	0
70	0	70	0
80	1	80	0
90	1	90	0
100	0	100	0

Average percentage of infection: Sprayed, 1.7; unsprayed, 4.2.

TABLE 12.—RELATIVE PERCENTAGE OF ANTHRACNOSE INFECTION ON SPRAYED AND UNSPRAYED PLATS.

BEANS PLANTED IN ROWS.

Sprayed.		Unsprayed.	
Percentage infection.	Number of plants.	Percentage infection.	Number of plants.
10	5	10	15
20	1	20	9
30	0	30	3
40	0	40	3
50	1	50	5
60	1	60	3
70	0	70	1
80	1	80	2
90	0	90	5
100	0	100	1

Average percentage of infection: Sprayed, 2.6; unsprayed, 17.5.

The plants pulled and graded were threshed and the diseased beans carefully picked from samples of 500 seeds. The data were as follows:

TABLE 13.—PERCENTAGE OF DISEASED BEANS FROM SPRAY PLOTS.

Treatment of plots.	Method of planting.	Number of beans in sample.	Number of beans infected with blight.	Number of beans infected with anthracnose.	Per cent of blight.	Per cent of anthracnose.	Average per cent blight.	Average per cent anthracnose.
Sprayed.....	In hills..	500	54	10	10.8	2.0	9.7	1.9
		500	43	9	8.6	1.8		
Not sprayed...	In hills..	500	37	11	7.4	2.2	8.9	3.3
		500	52	22	10.4	4.4		
Sprayed.....	In rows..	500	58	14	11.6	2.8	9.4	2.3
		500	36	9	7.2	1.8		
Not sprayed...	In rows..	500	42	27	8.4	5.4	8.7	5.4
		500	45	27	9.0	5.4		

From these results it will be seen that although the blight was not checked by spraying, the anthracnose was decreased. Particularly noteworthy is the reduction of anthracnose brought about by the use of hill planting.

It is the writer's opinion that bean anthracnose can be greatly reduced, if not wholly controlled by spraying with Bordeaux mixture. The success of spraying, however, depends upon the thoroughness of application and upon the time of the first application of the spray. If possible, the first application should be made while the cotyledons or seed leaves are still on the seedling. It is from these infected cotyledons that the anthracnose spreads to the stem. In this stage of the growth of the plant, the disease is most readily checked.

It is possible, but as yet not demonstrated, that bean blight could be reduced by spraying, if the first application is made soon enough. Our data, however, are insufficient to make any recommendation for spraying to control blight.

SEED TREATMENTS.

Several important factors at once enter into the feasibility of seed treatment. They are as follows: The effect of the treatment upon the slipping of the seed coat, the deleterious effect of the treatment upon the seed germ, the penetrating power of the fungicide or bactericide, and the toxicity of this agent to the fungus or bacteria.

In taking up this method of control, it was thought that either some chemical in solution, or heat, (wet or dry), might be employed to kill the blight or anthracnose organisms without injuring the seed.

The anthracnose fungus and blight bacteria are present, either within or upon diseased bean seed. The former usually occurs as mycelial threads, more or less deeply rooted in the tissue of the seed, although spores may also be found in the typical diseased spots or adhering to seemingly clean seed. The latter are found beneath seed coats, between cotyledons, or upon the surface of infected seeds.

It is a well-known fact that when beans are soaked a certain length of time, the seed coats will become loosened, and slip off. Such a result renders the seeds of no value for planting. When the seeds are soaked in chemical solutions of certain strengths, the seed germ lying just beneath the seed

Plate I. Bean Seedlings three weeks old, showing the effects of the anthracnose. These plants later rotted at the lower stem cankers.

Plate II. Fig. 1.—Late stages of Bean Anthracnose (right) and Bean Blight (left) on pods. Bean Blight shows bacterial crusts.

Plate II. Fig. 2.—Early stages of Bean Blight on immature pods.

Plate III. Bean leaves affected with the Bacterial Blight.

Plate IV. Mature bean pods affected with the Blight, showing the bacterial crusts.

coat is killed and they cannot be used for planting. Likewise, wet and dry heat at certain temperatures kill the seed.

Also seeds soaked in a chemical solution at sufficient concentration to kill the fungus or bacteria but not the seed germ, may not be able to penetrate to the organism deeply embedded within the tissue.

If one could be certain that the pathogene were merely on the surface of the seed, the control of both diseases would be a more simple matter. The uncertainty as to the depth of infection, however, makes the matter far more complex.

Our experiments were carried on both in the laboratory and greenhouse under controlled conditions and in the field. The seed was treated, then placed in sterile moist chambers between moist filter paper to germinate. The effect of each treatment upon the germination of bean seed was first determined.

Diseased seed was then treated and germinated as before, or planted in tubes of moist sterilized sand, and the seedlings grown. The seedlings in the tubes were sprayed with sterile water each day to determine whether or not the pathogene could be washed from the diseased cotyledons to the stem. This method of testing the viability of the organisms seemed very efficient, since the plants were placed in an environment equaling the most severe weather conditions. However, the above tests were not applied in the experiments of 1913 and 1914, and this probably accounts to some extent for the negative field results for these years.

The following seed treatments were tested:

1. Seed was soaked for ten minutes at 55° C. in a solution of mercuric chloride and commercial sodium nitrate. (One liter of mercuric chloride, 1-1000, to which was added one kilogram of commercial sodium nitrate.*)
2. Seed was soaked in the same solution for the same length of time, but the solution was not heated.
3. Seed was soaked for twenty minutes in a mercuric chloride solution 1-1000, not heated.
4. Seed was soaked in a fifty per cent solution, by weight, of zinc chloride, not heated, for five minutes.
5. Seed was soaked for twenty minutes in 40% formaldehyde, diluted 1-100.
6. Seed was heated in an electric oven for 30 minutes, at a constant temperature of 70° C.
7. Seed was heated in an electric oven for 30 minutes, at a constant temperature of 80° C.

The seeds used as checks were untreated.

The effect of these treatments upon the germination of the seed was previously determined, the results being given in the following table:

TABLE 14.—EFFECT OF TREATMENTS ON GERMINATION OF SEED.

Number of treatment.	Treatment.	Percentage of germination.
1	Mercuric chloride and sodium nitrate solution 10 minutes at 55° C	92
2	Mercuric chloride and sodium nitrate solution, not heated	92
3	Mercuric chloride solution, 1-1000, 20 minutes, not heated	91
4	Zinc chloride solution, 50% 5 minutes	85
5	40% solution of formaldehyde, 1-100, 20 minutes	85
6	Dry heat, 70° C. 30 minutes	93
7	Dry heat, 80° C. 30 minutes	93
8	Hot water, 50° C. 10 minutes	93
9	No treatment, checks	100

*The sodium nitrate was added to bring the solution to such concentration that the seed coats could not take up water from it.

DIAGRAM OF EXPERIMENTAL PLOTS IN FIELD 12.—1914.

E. W. Tr. 3	E. W. Ch.	Cull Tr. 3	Cull Ch.	E. W. Tr. 4	Cull Ch.	E. W. Tr. 6	Cull Ch.	E. W. Tr. 7	Cull Ch.	E. W. Tr. 7	Cull Ch.	E. W. Ch.	California
E. W. Tr. 1	E. W. Tr. 2	Cull Tr. 1	Cull Tr. 2	E. W. Ch.	Cull Tr. 4	E. W. Ch.	Cull Tr. 6	E. W. Ch.	Cull Tr. 7	E. W. Ch.	Cull Tr. 5	CHP	Idaho
E. W. Bord.*	E. W. Ch.	Cull Bord.	Cull Ch.	E. W. L. S.†	E. W. Ch.	Cull L. S.	Cull Ch.	E. W. Bord.	Cull Ch.	Cull Ch.	Cull Bord.	Cull Ch.	Arizona

Soil inoculated with nodule bacteria.

*Bordeaux Mixture.
†Lime sulphur.

Two grades of seed were treated for the 1914 field experiment, badly diseased beans and Early Wonder beans which were sold on the market for seed purposes. The former grade of seed is referred to as cull seed.

The two lots of treated seed and the checks for each treatment were planted in plots approximately 22 feet square. For each plot of treated seed there was a check plot of the same size of untreated seed. The whole experimental field measured 330 feet by 66 feet. The seed treatment plots were arranged three in a row as shown in the accompanying diagram.

The seed was treated June 3, 1914, and planted the following day. When the seedlings were about five inches in height, careful examinations were made of all the plants in each of two rows of each plot for signs of disease cankers on the stems. The percentage of affected seedlings found in each plot at this time is given in the following table:

TABLE 15.—PERCENTAGE OF DISEASED SEEDLINGS FROM TREATED AND UNTREATED EARLY WONDER SEED.—M. A. C. PLOT.—1914.

Number of treatment.	Treatment given seed.	Plants examined.	Cankers found.	Percentage cankered.
1	Soaked 10 min. at 50° C. in sodium-nitrate-mercuric chloride solution	132	0	0
	Check, untreated	187	1	0.55
2	Soaked 10 min. at 18° C. in sodium-nitrate-mercuric chloride solution	145.	0	0
	Check, untreated	162	1	0.61
3	Soaked 20 min. at 18° C. in mercuric chloride, 1-1000	*54	1	1.85
	Check, untreated	227	0	0
4	Soaked 5 min. at 18° C. in 50% zinc chloride solution	150	1	0.66
	Check, untreated	139	0	0
5	Soaked 20 min. at 18° C. in formalin 1-100	*19	0	0
	Check, untreated	115	1	0.86
6	Heated 30 min. at 70° C. at constant temperature.	123	0	0
	Check, untreated	128	0	0
7	Heated 30 min. at 80° C. at constant temperature.	114	1	0.877
	Check, untreated	152	1	0.65
	Average percentage of cankered plants in all check plots	.....	.....	0.38

*All plants in plot examined.

TABLE 16.—PERCENTAGE OF DISEASED SEEDLINGS FROM TREATED AND UNTREATED CULL SEED. M. A. C. PLOT.—1914.

Number of treatment.	Treatment given seed.	Plants examined.	Cankers found.	Percentage cankered.
1	Mercuric chloride and sodium nitrate solution 10 min. at 55° C	109	6	5.5
	Check	125	40	32
2	Mercuric chloride and sodium nitrate solution, not heated	98	4	4.18
	Check	113	12	10.67
3	Mercuric chloride solution, 1-1000, 20 minutes, not heated	144	2	1.38
	Check	110	7	6.36
4	Zinc chloride solution, 50%, 5 min	112	0	0
	Check	86	4	5.38
5	40% solution of formaldehyde, 1-100, 20 minutes	*34	0	0
	Check	96	4	4.16
6	Dry heat, 70° C., 30 minutes	97	7	7.21
	Check	86	4	4.65
7	Dry heat, 80° C., 30 minutes	103	6	5.82
	Check	94	9	9.57
	Average percentage of cankered plants in all checks	.....	.....	13.98

*All plants in plot examined.

Further seed treatments were tested in the field at Sandusky, Fremont,* Saginaw, and Port Huron.* In the Sandusky field plots both cull beans and average clean seed were used. The treatments outlined on page 26 were employed with the exception of No. 5. Four plots of each kind of seed, untreated, were left as checks. The soil of these plots was a well drained sandy loam and the plots were well cultivated.

The seed was treated June 5th, 1914, and planted June 10. On July 17th the young plants in alternate rows were examined for stem cankers. The percentage of cankers found is given in the following table:

TABLE 17.—PERCENTAGE OF DISEASED SEEDLINGS FROM TREATED AND UNTREATED EARLY WONDER SEED. SANDUSKY PLOT.

Number of treatment.	Treatment given seed.	Plants examined.	Cankers found.	Percentage cankered.
1	Mercuric chloride and sodium nitrate solution 10 minutes at 55° C	223	18	8.07
2	Mercuric chloride and sodium nitrate solution, not heated	159	9	5.66
3	Mercuric chloride solution, 1-1000, 20 minutes, not heated	132	6	4.54
	Check	297	4	1.34
4	Zinc chloride solution, 50%, 5 minutes	107	6	3.60
	Check	286	10	3.49
6	Dry heat, 70° C., 30 minutes	267	3	1.12
	Check	241	4	1.65
7	Dry heat, 80° C., 30 minutes	251	2	0.79
	Check	291	12	4.12
	Average percentage of cankered plants in all check plots			2.65

TABLE 18.—PERCENTAGE OF DISEASED SEEDLINGS FROM TREATED AND UNTREATED CULL SEED. SANDUSKY PLOT.

Number of treatment.	Treatment given seed.	Plants examined.	Cankers found.	Percentage cankered.
1	Mercuric chloride and sodium nitrate solution 10 minutes at 55° C	102	7	6.86
2	Mercuric chloride and sodium nitrate solution, not heated	213	14	6.57
3	Mercuric chloride solution, 1-1000, 20 minutes, not heated	140	9	6.42
	Check, untreated	193	19	9.84
4	Zinc chloride solution, 50%, 5 minutes	63	6	9.52
	Check, untreated	159	15	9.52
6	Dry heat, 70° C., 30 minutes	158	12	7.59
	Check, untreated	186	16	8.60
7	Dry heat, 80° C., 30 minutes	178	14	7.92
	Check, untreated	189	13	6.87
	Average percentage of cankered plants in all check plots			8.70

*The writer was unable to obtain records of infection on the seedlings grown on the plots at Fremont and Port Huron.

TABLE 19.—PERCENTAGE OF DISEASED SEEDLINGS FROM TREATED AND UNTREATED EARLY WONDER AND CULL SEED. SAGINAW PLOT.

Number of treatment.	Treatment given seed.	Kind of seed.	Plants examined.	Cankers found.	Percentage cankered.
1	$NaNO_3 + HgCl_2$, 1-1000 at 55° C.	EW	100	10	10
2	$NaNO_3 + HgCl_2$, cold.....	EW	100	8	8
3	$HgCl_2$, 1-1000 at 20° C.....	EW	100	10	10
	Check.....	EW	100	14	14
4	$ZnCl_2$, 50% solution.....	EW	100	26	26
	Check.....	EW	100	15	15
1	$NaNO_3 + HgCl_2$, 1-1000 55°....	Cull	100	29	29
2	$NaNO_3 + HgCl_2$, 1-1000 cold...	Cull	100	57	57

From the preceding tables it is clearly seen that the seed treatments employed had no appreciable effect upon reducing the initial infection from the anthracnose and blight. In the mature plants no difference in amount of infection could be seen. This conclusion was further confirmed by the results obtained on the College plot in 1915, the data of which are given in Table 20.

TABLE 20.—AVERAGE PERCENTAGE OF INFECTION PER SERIES ON PLANTS OF EACH TREATMENT AND CHECKS.

Treatment.	1.	2.	3.	4.	5.	6.	7.	8.	Check.
Anthracnose percentage.	54.96	69.98	53.08	62.02	.....	52.61	57.44	57.10	60.33
Treatment.	1.	2.	3.	4.	5.	6.	7.	8.	Check.
Blight percentage.	67.93	59.94	38.70	57.32	.....	51.36	66.64	55.67	66.26

While there seemed to be no injury to the seed in the laboratory test from these treatments, these results were not sustained in the field experiments. It was found that the treatment with formaldehyde almost inhibited germination under field conditions. In the 1914 plot, approximately 8% and in the 1915 plot 5% germination resulted from the seed so treated. Edgerton recommends treating bean seed with mercuric chloride solution 1-1000 for twenty minutes to control the blight; Brandon, (1899) treated seed with formaldehyde to control the anthracnose. Our results show that this treatment not only does not control blight, but quite materially lessens the germination of the seed. The effect upon germination is so deleterious as to preclude its use upon a commercial scale. We have repeatedly obtained the blight organism from between the cotyledons and beneath the seed coat of beans soaked for twenty minutes in this strength of mercuric chloride solution. Evidently Edgerton employed slightly infected seed for his treatments with mercuric chloride solution. Formaldehyde did not control the anthracnose in our experiments.

In order to determine whether or not these seed treatments affected the susceptibility of the plants to anthracnose and the blight, a series of experiments was carried on in the greenhouse and the field.

In the greenhouse, the conditions of light, temperature, humidity, and

soil moisture were controlled as far as possible. Two varieties of seed, the Early Wonder and Robust, were employed.

The field experiment was carried on during the season of 1915, using only the Early Wonder seed. The methods employed were as follows: Disease-free seed was treated and planted in pots of sterile soil, the moisture content of which was kept as nearly constant as possible thruout the experiment. When the plants were in full foliage, the anthracnose and blight organisms were sprayed upon the respective series of plants. The percentage of leaf area infected was carefully determined. In the field experiment, the treated seed was planted and as soon as the plants were beginning to pod, the infected ones were rogued out, leaving only the healthy ones. These were then sprayed with the blight and anthracnose organisms, three plots of plants from treated seed being used for inoculation. At the maturity of the plants they were graded as to the percentage of infection found. The data* obtained in these experiments show that the seed treatments did not affect the relative susceptibility of the plants to either disease.

Other treatments of the seeds were tested as follows: Formaldehyde gas, solutions of copper sulphate, with and without the addition of sulphuric acid or oxalic acid, mercuric chloride and bleaching powder. The treated diseased seed were planted in test tubes of moist sterile sand, and the seedlings sprayed each day with sterile water in order to secure the most favorable condition for the development of the anthracnose or blight organisms. The results obtained are given in tabulated form as follows:

TABLE 21.—EFFECT OF FORMALDEHYDE GAS UPON SEED GERMINATION AND COLLETOTRICHUM LINDEMUTHIANUM.

Kind of seed.	Number seed treated.	Number germinated.	Per cent germination.	Number diseased seedlings.
Hand picked	200	160	80	100
Badly affected with Anthracnose	200	82	41	82

Owing to the unfavorable results obtained with the above treatments, no further tests were made.

TABLE 22.—EFFECT OF SEED TREATMENT ON GERMINATION OF CLEAN BEANS.

Treatment.	DURATION OF TREATMENT. MINUTES. 5.	10.	12.	15.	18.	20.	22.	25.	28.	30.	Check.
0.2 % $CuSO_4$ + 0.1 % H_2SO_4 per cent germination	95	95	100	95	95	95	75	65	40	39	100
0.3 % $CuSO_4$ + 0.1 % H_2SO_4 per cent germination	95	100	100	90	90	100	85	80	60	55	95
0.4 % $CuSO_4$ + 0.1 % H_2SO_4 per cent germination	90	95	95	90	95	100	80	†35	55	70	100
0.5 % $CuSO_4$ + 0.1 % H_2SO_4 per cent germination	90	90	90	90	70	90	70	†45	50	†35	100

*The complete data are given in a thesis by the writer. See Bibliography.

†Beans attacked by molds and bacteria.

20 seeds were used in each test.

These tests were employed with beans affected with blight or anthracnose to find what effect they had upon the germination of seed. The duration of the treatment in each case was twenty minutes. The results are tabulated below.

TABLE 23.—EFFECT OF COPPER SULPHATE + SULPHURIC ACID ON GERMINATION OF DISEASED SEED.

Kind of seed.	Solution.	Per cent germination.	Kind of seed.	Solution.	Per cent germination.
Anthracnose..	$CuSO_4$.... 0.2% + H_2SO_4.. 0.1%	90	Blighted	$CuSO_4$.... 0.2% + H_2SO_4.. 0.1%	88
	$CuSO_4$.... 0.3 + H_2SO_4.. 0.1	80		$CuSO_4$.... 0.3 + H_2SO_4.. 0.1	70
	$CuSO_4$.... 0.4 + H_2SO_4.. 0.1	70		$CuSO_4$.... 0.4 + H_2SO_4.. 0.1	60
	$CuSO_4$.... 0.5 + H_2SO_4.. 0.1	40		$CuSO_4$.... 0.5 + H_2SO_4.. 0.1	40
	Check.....	90		Check.....	88

Having found the effect of the treatment upon the germination of the diseased seed, the effect upon the disease organisms was determined. The treated diseased beans were planted in test tubes of moist sterile sand and allowed to germinate. Twenty seeds of each kind were used. These seedlings were sprayed daily with sterile distilled water. The experiment continued three days after the seedlings came out of the sand. The results are as follows:

TABLE 24.—CHECK, UNTREATED SEEDS; GERMINATION AND AMOUNT OF DISEASE.

Kind of seed.	Per cent of germination.	Percentage infection on	
		Cotyledon.	Stem.
Anthracnosed.....	50	50	30
Blighted.....	60	60	15

Having found the percentage of germination of diseased seeds, beans affected with the anthracnose and blight were treated. In each of these tests twenty seeds were soaked in the solutions for twenty minutes, and each planted in a test tube partially filled with sterile moist sand. The seedlings were examined at intervals for evidence of infection both on the cotyledons and the stems. The following table gives the effect upon the pathogenes and upon the germination of the seed.

TABLE 25.—EFFECT OF COPPER SULPHATE + SULPHURIC ACID UPON THE PATHOGENE AND GERMINATION OF THE SEED.

Treatment.	Anthracnosed beans.			Blighted beans.		
	Per cent germination.	Per cent infection.		Per cent germination.	Per cent infection.*	
		Cotyledons.	Stems.		Cotyledons.	Stems.
$CuSO_4$..... 0.2% + H_2SO_4.... 0.1	50	50	30	60	60	15
$CuSO_4$..... 0.3 + H_2SO_4.... 0.1	55	50	25	50	45	5
$CuSO_4$..... 0.4 + H_2SO_4.... 0.1	0	.....	.....	5	5	0
$CuSO_4$..... 0.5 + H_2SO_4.... 0.1	10	0	0	10	5	0

*The percentage of infection is calculated on total number of seeds which germinated.

In like manner diseased beans were treated for twenty minutes with a 1-1000 solution of mercuric chloride to which oxalic acid was added as a penetrant in various percentages. While the percentages of germination were higher, these treatments failed to kill either pathogene. The control given in this table was also used for the preceding treatments with copper sulphate and suphuric acid, carried on at the same time.

TABLE 26.—EFFECT OF MERCURIC CHLORIDE + OXALIC ACID UPON THE PATHOGENE AND THE GERMINATION OF THE SEED.

Treatment.	Anthracnosed beans.			Blighted beans.		
	Per cent germination.	Per cent infection.		Per cent germination.	Per cent infection.	
		Cotyledons.	Stems.		Cotyledons.	Stems.
$HgCl_2$..... 1–1000 + 2 % Oxalic acid	70	70	30	60	55	10
$HgCl_2$..... 1–1000 + 3 % Oxalic acid	75	40	10	50	45	0
Check untreated....	65	65	15	80	65	40

In the case of each treatment with copper sulphate and mercuric chloride, poured plates were made either from the infected cotyledons or stems and the organisms recovered. No inoculation tests were made with the anthracnose or blight organisms but from comparison with pure cultures of *Colletotrichum lindemuthianum* and *Bacterium phaseoli* and in microscopical examinations they appeared to be identical.

Clean beans were treated for different lengths of time with a two per cent solution of zinc chloride. The effect upon germination was as follows:

TABLE 27.—EFFECT OF ZINC CHLORIDE UPON GERMINATION: CHECK.

Treatment.	Length of time.	Percentage of germination.
2 % solution of zinc chloride	10 minutes	83
	12 minutes	94
	15 minutes	86
	18 minutes	91
	20 minutes	90
Check untreated		95

Beans affected with the anthracnose and blight were treated for ten minutes in the same solution to determine its effect upon the pathogenes. Each bean was planted in a test tube of moist sterile sand.

TABLE 28.—EFFECT OF ZINC CHLORIDE UPON THE PATHOGENE AND GERMINATION OF THE SEED.

Treatment.	Anthracnosed beans.		Blighted beans.	
	Per cent germination.	Per cent infection on stems.	Per cent germination.	Per cent infection on stems.
2 % zinc chloride solution	70	100	60	50

Microscopical mounts were made from the diseased portions of the stems and examined under the high power. In case of the blighted beans, while only 50% of the seedlings showed bacterial infection, the remainder were infected with the anthracnose.

Tests were made of the effect of bleaching powder* (Calcium hypochlorite) upon the germination of healthy seeds with different concentrations of the solution and for different lengths of time. The following results were obtained:

TABLE 29.—EFFECT OF CALCIUM HYPOCHLORITE UPON GERMINATION OF SEEDS: CHECK.

Treatment.	Number of seeds used.	Duration of treatment.	Per cent germination.	Duration of treatment.	Per cent germination.
10 % solution $CaOCl_2$	50	30 min.	80	1 hr.	90
15 % solution $CaOCl_2$	50	30 min.	92	1 hr.	76
20 % solution $CaOCl_2$	50	30 min.	80	1 hr.	90
25 % solution $CaOCl_2$	50	30 min.	86	1 hr.	50
30 % solution $CaOCl_2$	50	30 min.	100	1 hr.	72
35 % solution $CaOCl_2$	50	30 min.	100	1 hr.	92
Check sterile distilled water	50	30 min.	100	1 hr.	100

Twenty beans badly infected with anthracnose and twenty clean beans were treated for thirty minutes in a 25% solution of bleaching powder. Five beans were planted in each of four tubes of moist sterile quartz sand.

*After preparing this solution, the supernatant liquid was poured off and the seed soaked in it, as employed by Wilson (1915).

These tubes were two inches in diameter and twelve inches in length. The seedlings were sprayed with sterile distilled water each day and examined for disease lesions on the stems and leaves. The following results were obtained:

TABLE 30.—EFFECT OF CALCIUM HYPOCHLORITE UPON THE PATHOGENE AND GERMINATION OF THE SEED.

Treatment.	Number seed planted.	Per cent germination.	Number infected plants.	Per cent infection.	Parts affected.
25 % $CaOCl_2$ for 30 min....	20	65	10	77	Stem and leaf.
Checks untreated.....	20	70	14	100	Stem and leaf.

Further tests were made with the bleaching powder solution for different lengths of time, on seeds affected with the anthracnose. In these tests $16\frac{2}{3}\%$ and 20% solutions of Calcium hypochlorite were used. The duration of the treatment varied from 30 minutes to one hour and thirty minutes. The same methods of procedure were employed as in the previous tests.

TABLE 31.—EFFECT OF CALCIUM HYPOCHLORITE UPON THE PATHOGENE AND GERMINATION OF THE SEED.

20 SEEDS TO EACH TREATMENT.

Treatment.	Duration of treatment.	Number plants growing.	Per cent germination.	Number infected plants.	Per cent infection.	Number clean plants.	Per cent clean plants.
CaOCl $16\frac{2}{3}$ % sol..	30 min.	10	50	3	30	7	70
CaOCl $16\frac{2}{3}$ % sol..	45 min.	10	50	2	20	8	80
CaOCl $16\frac{2}{3}$ % sol..	60 min.	7	35	0	0	7	100
CaOCl $16\frac{2}{3}$ % sol..	1½ hrs.	5	25	1	20	4	80
CaOCl $16\frac{2}{3}$ % sol..	1½ hrs.	15	75	5	$33\frac{1}{3}$	10	$66\frac{2}{3}$
No treatment....		10	50	1	20	9	90

TABLE 32.—EFFECT OF CALCIUM HYPOCHLORITE UPON THE PATHOGENE AND GERMINATION OF THE SEED.

25 SEEDS TO EACH TREATMENT.

Treatment.	Duration of treatment.	Number plants growing.	Per cent germination.	Number infected plants.	Per cent infection.	Number clean plants.	Per cent clean plants.
$CaOCl_2$ 20 % sol..	45 min.	7	28	3	43	4	57
$CaOCl_2$ 20 % sol..	1 hr.	5	20	0	0	5	100
$CaOCl_2$ 20 % sol..	1½ hr.	6	24	0	0	6	100
$CaOCl_2$ 20 % sol..	1½ hr.	4	16	1	25	3	75
Check, no treatment.....		4	16	1	25	3	75

These data while giving some idea as to the effect of the treatment upon the pathogene are not reliable because of the low germination in both the treated and untreated seeds. From the results obtained from treating good seed with a 35% solution of bleaching powder, it was thought advisable to treat some of the seed used in the field plot in this manner. Early Wonder

seed showing a "pick" of two pounds was so treated and planted June 13th, 1916. This plot included five rows, 165 feet long, planted 30 inches apart. The seedlings were examined eight days after planting, but few disease lesions were found upon the stems. On August 8th, both the anthracnose and blight were found to a small extent in this plot. This treated plot showed less anthracnose than the check adjacent, although there was about the same degree of infection on both from the blight. It seems very probable that the treatment with bleaching powder solution would be effective against both bean anthracnose and blight in case of surface infection on the seed. On account of the manner of dissemination of the blight pathogene, seed so treated should be planted away from all untreated seed in a field in which at least a three year rotation has been carried out.

A plot of 14 rows, 165 feet long, was planted to Early Wonder seed, of the same lot as the preceding, which had been treated by sprinkling with a formaldehyde solution made up in the proportion of one pint commercial formaldehyde to thirty gallons of water. After sprinkling, the beans were covered with a wet sack and allowed to stand over night. After drying they were planted. This plot was examined on June 21. The treatment delayed germination about three days and at first the seedlings did not grow as rapidly as those untreated but more rapidly than those treated with 35% solution of bleaching powder. There was no evidence of such injury to the seed as occurred in the case of the beans treated with bleaching powder solution. Very little anthracnose was found when this plot was examined on August 8th, but the blight was prevalent.

The lack of serious infection from the anthracnose organism was due in part no doubt to the effect of the treatments. But on account of the very hot dry weather of the 1916 season, the results obtained cannot be regarded as conclusive.

The results of the seed treatments carried on for a period of three years both in the greenhouse and field may be summed up as follows:

1. In case of heavy infection, the seed treatments employed did not kill the pathogene without also injuring the seed.

2. In case of light infection or surface infection it seems possible to control the disease in a large degree by employing seed treatments. Those treatments found to be most efficient are: (1) Soaking the seed for thirty minutes in a 35% solution of bleaching powder; and (2) sprinkling the seed as in the treatment of oat smut, with a solution of formaldehyde, one pint of formaldehyde to thirty gallons of water.

SEPARATION OF DISEASED AND HEALTHY SEED BY SPECIFIC GRAVITY METHODS.

Gain (1893) reports the results of his work on the difference in density between clean and diseased beans. Dwarf lima beans were employed in the tests. The diseased beans were affected with the anthracnose. He found that there was a decrease from 3.43% to 4.8% in the density of the diseased seed.

At the beginning of the bean disease investigation at this station Dr. G. H. Coons carried on some experiments along these lines. He found it possible to separate badly diseased beans from clean ones by placing them in a solution of sodium nitrate of a given concentration, in which the diseased beans came to the surface. The writer continued these experiments using severely infested beans and those only slightly affected with the anthracnose. In every case it was found that the badly diseased seed would rise to the surface

of the solution. Those beans only slightly infected sank to the bottom of the container along with the clean seed.

In every lot of seed there is a wide variation as to size and weight of the individual beans. This adds to the difficulty in separating all the diseased and clean seed. From our experiments it seems that this method of separation of diseased and clean beans, on a large scale, would not be reliable, and could not be recommended to the grower, who wished to clean his own beans for seed purposes.

SEED SELECTION.

While seed selection is an excellent precautionary measure to practice, it is not to be regarded as a means of completely controlling either the bean anthracnose or the bean blight. The fact that seed beans are white and without any discoloration, is not absolute proof that all the beans are disease-free. In our germination experiments it has been frequently found that the plumule of apparently clean beans, may show infection from either the anthracnose or the blight. While it is far better to use for planting, seeds which show no signs of infection, such a practice will not insure the total freedom of the crop from initial infection from either disease.

FIELD SELECTION.

Field selection of bean seed is a common practice in many localities of this state. In this practice the grower selects for seed purposes those plants showing the greatest vigor and productiveness, and from the pods of these plants the seed is taken. No especial attention is ordinarily paid to securing pods free from disease. It is the practice, however, to carefully hand-pick the seed from these pods. This practice of field selection, while tending to insure a more productive crop from such seed, does not reduce to any great extent the amount of disease. It must be said that the practicing of field selection will lead to a much better yield than the planting of ordinary unselected seed. Pod selection of seed, to eliminate the anthracnose and the blight not only covers the good points of field selection, but also eliminates the anthracnose and greatly reduces the bacterial blight.

POD SELECTION.

A much better practice is that of pod selection of seed. Altho pod selection is a rather tedious method of securing clean seed, the results to be derived from this practice will fully repay the grower for his trouble. When the beans are mature some pods will be found to be free from disease. These disease-free pods are pulled from the most vigorous plants. They are then dipped in a solution of mercury bi-chloride 1-1000 for ten minutes and allowed to dry in the sun, away from all other beans and trash from the bean field, to prevent contamination of the pods. The pods are shelled and the disease-free seeds are placed in air tight containers, such as mason jars, to prevent contamination. These disease-free beans are used the following season for planting a seed plot. This plot should be on fertile soil upon which beans have not been grown previously, and away from all other beans. The crop from this clean seed should be disease-free, or practically so, depending upon the location of the plot with reference to infected fields. The seed from this plot should be used in planting a larger plot the following season. The process is repeated from year to year until sufficient seed is obtained

to plant a large acreage. If either the anthracnose or the blight should appear in the seed plot, the affected plants should be pulled out and burned. Although this practice will give a crop free from anthracnose, it will not entirely eliminate the blight. The presence of the blight bacteria in the soil and trash, and the ease with which they are disseminated renders its absolute control by such a method impossible, although it can be reduced to a negligible minimum. *This method of pod selection is, we believe, at present the most practicable control measure for these bean diseases.* Once the grower secures sufficient seed for field planting, and sees the good results, no great difficulty will be experienced in getting him to continue the work. Pod selection is practiced by several growers in this state, and with excellent results.

DISEASE RESISTANT VARIETIES.

The development of disease-resistant hosts is the natural, most convenient, and most satisfactory method of combating plant diseases. This control method, too, has its drawbacks. A plant which is immune or highly resistant to its special pathogene may not be marketable or may not produce marketable fruit. In the case of wheat, where varieties are grown because of special characteristics, it is very difficult to find a variety having all of the good qualities and at the same time resistant to the rusts.

The planting of seed resistant to fungus or bacterial disease organisms, has been productive of excellent results, however, in some cases. Orton (1903) found a variety of cow peas resistant to the Fusarium Wilt fungus, and also (in like manner) a resistant variety of cotton was found, (1900). By crossing he developed a variety of watermelons resistant to wilt (1911). Jones and Gilman (1915) after a long series of experiments, have developed a variety of cabbage resistant to the organism producing yellows. A wilt resistant flax has been found by Bolley (1903). Bain and Essary (1905) from a field selection have developed an anthracnose-resistant variety of clover. Barrus (1915) working with red kidney beans, has found a variety which while not immune to anthracnose, is highly resistant to it. This variety of beans, however, grown in this state is more susceptible to the blight than many of our native varieties.

The writer has made a careful search during the past three years for a variety of white pea beans showing resistance to either the anthracnose or blight, but the results so far have been negative. This search is to be continued, and it is hoped, with more success.

DISEASE-ESCAPING AND DISEASE-ENDURING VARIETIES.

As Orton (1911) has pointed out, that although a host plant may not be resistant or immune to disease organisms, it may endure or escape the attacks of these organisms. By disease-endurance, is meant the ability of the plant to bear up and ripen its fruit under severe infection. By disease-escape, is meant the ability to avoid infection, wholly, or to a large extent, under severe disease conditions. In our work, we have found a variety of beans known as the Early Wonder (formerly Little Early Scofield) to be disease-escaping. This variety of white pea beans, according to Mr. W. W. Tracy of the United States Department of Agriculture, came originally from western New York. He writes: "....We first heard of it in 1890 as being very popular in western New York where it is said to have originated from selection and development of a single plant by a Mr. Scofield. Just where he was

located beyond the vicinity of somewhere between Rochester and LeRoy, we do not know. We think the bean was first listed by J. Harris in 1892 and that he claimed to be the originator. Under the name Early Marrow Pea, D. M. Ferry & Co. offered in 1884 a bean which was very similar in all its characteristics to the Scofield. We think the Early Wonder Pea offered by Armsby of New York in 1903 and Salzer in 1895, was essentially the same as the Scofield....." The variety, as far as we can find, was first grown in Michigan by a farmer near Okemos. Some of the seed was taken to Remus, Michigan, by Mr. D. Mansfield and his brother. It was grown by them in the garden and later in the field until sufficient seed was obtained to put it on the market. They changed the name on account of the quality of the seed, productivity and early maturity of the plants, to Little Early Wonder. The seed under this name has been sold by D. Mansfield & Co., and other bean jobbers since about 1910.

From reports of this variety of beans given us by various bean jobbers, it was decided to test it out thoroughly. During the past three years we have carefully observed several hundreds of acres of these beans. During the seasons of 1914 and 1915, all possible data were collected upon the growth period, productivity, and the behavior under disease conditions of the Early Wonder beans. Fields were inspected and samples of the seed carefully examined for evidences of the anthracnose and the blight. In every case a gomparison between this variety and the grower's own seed was given by the crowers and jobbers handling both kinds of seed. The data so obtained from many parts of the state in 1914 and 1915 may be summarized as follows:

1. Early Wonder beans mature from 10 days to 2 weeks earlier than the ordinarily grown sorts.
2. The average yield is 20 bushels per acre.
3. The average pick is 2 pounds per bushel less than home grown seed.
4. They ripen more evenly and produce a better grade of seed, than the home grown beans.
5. The pods hang high, thus lessening the damage from rotting in contact with the soil.

From the above summary it will be seen that it is more profitable to plant Early Wonder beans than the kind of seed ordinarily planted by bean growers.

It must be borne in mind that this variety of beans is not resistant to either the anthracnose or blight. On account of the early ripening of the plants, the pods begin to harden at about the time that the disease organisms are ready to attack the seed. This rapid hardening of the pod then prevents, to a large degree, the organisms from attacking the seed, since these disease organisms do not penetrate the mature pods.

In 1915 when the planting of Early Wonder beans was recommended as a palliative, it was possible to secure this variety unmixed. At the present time we know of but one bean jobber who has kept this variety of seed unmixed, and it can be secured only in small quantities.

NATIVE WESTERN SEED.

In an effort to find the relative prevalence of the bean anthracnose and blight on western beans, many samples from different states were examined. These samples were sent from Idaho, Washington, California, and Arizona. These beans were all practically free from anthracnose and blight. Three kinds of white beans were received and in 1914 planted in test plots on the college farm as follows:

Lady Washington (California)
Small White (Idaho)
Tepary Beans (Arizona)

These beans were planted in plots along side of the native Michigan seed. Although they all were planted on the same day there was a great difference in the time of maturing, the native Michigan beans ripening in about 100 days while none of the western beans were mature at the time of the first heavy frost in October. Western seed beans were again planted in 1916, but with like results. It is evident that native western beans, although relatively free from disease, cannot be successfully used for seed in our state.

WESTERN GROWN MICHIGAN BEANS.

Washington Grown Early Wonder Beans:

In 1914 two quarts of Early Wonder beans, picking not over one pound per bushel, were sent out to the state of Washington. They were grown near Auburn by Mr. George Pfnister. A threshed sample of beans from this seed was sent back to us. Although the sample was not free from disease, there was much less evidence of blight and anthracnose than was found in average samples of beans grown in Michigan that year. Mr. Pfnister grew a second crop of Early Wonder beans and sent back a sample of mature plants picked at random from the field. Only one pod showed marked evidence of the blight and there were no pods affected by the anthracnose.

These tests showed the possibility of growing Michigan beans in a state where weather conditions are relatively unfavorable to disease.

Idaho Grown Michigan Beans:

It is a well known fact that many seed companies grow native beans in western states. These beans, however, are usually of the garden sorts and not white pea beans for field planting on a large scale. The A. J. Brown Seed Co., of Grand Rapids, grew a crop of about 100 bushels of Michigan beans in Idaho and brought them back to this state for planting in 1916. Samples of this seed were examined and found to be almost free from the blight, while there was no evidence of the anthracnose.

In order to demonstrate the value of planting such clean seed, field plots were planted in fourteen counties of the state. Three quarts of this seed was planted in each plot. For comparison, a like quantity of Early Wonder* beans and clean-picked† Michigan beans, and the grower's own seed were planted in adjoining plots. These plots were planted in the following counties which annually plant a large acreage of beans: Kent, Newaygo, St. Clair, Saginaw, Huron, Gratiot, Genesee, Grand Traverse, Mecosta, Sanilac, Ionia, Livingston, Oceana and Ingham. The plots in Ingham county were grown on the experimental plots on the college farm.

Each plot was personally inspected twice during the growing season, and samples of the threshed beans were examined in the laboratory. The field data on the Idaho grown Michigan beans show that these beans produce as well under Michigan conditions as the best native seed obtainable. These beans were also more free from diseases than ordinary commercial seed. In comparison with the clean-picked Michigan seed, there was little if any

*The Early Wonder seed picked two pounds per bushel on a commercial basis.

†Clean-picked Michigan beans is the name given to a lot of table-picked beans grown near Charlevoix, Michigan, and used in this experiment as representing seed which had been picked commercially as closely as possible.

difference in the amount of disease present, although the yield per acre was higher in most cases. When one considers the cost of preparing the clean-picked seed, it would seem more economical to use the Idaho-grown Michigan beans for seed purposes. The average yield per acre of the Early Wonder beans was greater than that of any of the other varieties.

Idaho Grown Early Wonder Beans:

Although it was demonstrated in 1915 that Michigan beans grown one season in Idaho and brought back to this state, were practically disease-free and yielded above the average, the yield was not so great as from Early Wonder seed. In order to secure seed beans from seed as little mixed as possible, Early Wonder beans from this state were grown in Idaho the following year.

In cooperation with the U. S. Department of Agriculture,* the experiment in the renovation of this variety of beans was carried on at the Government potato farm at Jerome, Idaho, and with growers in that locality, during the season of 1916.

The Early Wonder beans sent to Idaho for planting showed a commercial pick of two pounds per bushel, consisting almost entirely of beans affected with anthracnose. About eight acres of these beans were grown under contract by growers of the locality. Owing to severe frosts of August 20th and September 7th, the yield was greatly reduced, only 28.5 bushels being harvested. After receiving these beans, a representative sample of the lot was taken for examination. In this sample only 0.2% of the beans showed evidence of blight infection, while none of the beans showed any signs of infection from anthracnose.

While it is possible that there was some infection from the anthracnose upon the stems of the plants, it was thought that the dry hot climate of that region would inhibit its growth and dissemination to any great extent and prevent pod infection.

Idaho-grown Early Wonder beans were sent during the season of 1917, for planting to the following counties: St. Clair, Saginaw, Alpena, Cheboygan, Newaygo, Muskegon, Ottawa, Allegan and Kalamazoo. The amount sent to each county varied from one to five bushels. In addition some of this seed was grown in Monroe County, New York.† There was extreme variation in the behavior of the beans from this seed and seed grown in the various counties and on the college plots. This variation was also evident in the different localities of the same county. In some cases the seed germinated well, producing vigorous, well-podded plants, while in other cases germination was very poor and the plants weak and scantily podded. In Saginaw county the results were uniformly good; in Cheboygan county in all cases but one, these beans were practically a failure. On the experimental plats at the college these beans germinated well and ripened a fair crop of seed.

The variation in germination and growth of the Idaho-grown Early Wonder beans can be explained in two ways. Owing to the two early frosts which affected the growing crop in Idaho, the beans were small in size and did not fully mature. This immaturity, while not to be considered serious under normal conditions at planting, would handicap the germination of the seed and subsequent growth of the plants.

*We are indebted to Mr. O. A. Pratt, Pathologist, Bureau of Plant Industry, for the supervision of this experiment.

†The demonstration plats in New York State were under the supervision of Mr. L. A. Toan of the Monroe County Farm Bureau, to whom we are very grateful for cooperation.

Weather conditions at planting time were very unfavorable for the growing of beans. The season was late and the weather cold and damp. This delayed germination. Growers, fearing a repetition of the hot, dry season of 1916, planted their beans deeper than they are usually planted. The effect of this combination of cold, wet weather and deep planting was very evident even on light, sandy soils, but especially so on the heavier soils. Where the beans were planted the usual depth and early in the season, they produced a good stand of vigorous, well-podded plants. The unfavorable results obtained in many localities were not entirely due to the kind of seed planted, but more particularly to the character of the weather and the method of planting.

The amount of blight on these beans also varied as widely as their growth; this variation being evident in the different localities of a given county. Much of the infection from blight originated in the portion of the field planted to the grower's own seed; some of it, however, came from more or less isolated badly diseased plants from the Idaho-grown seed. In Saginaw county the infection from blight was noticeably less on the Idaho-grown beans. The reverse was true in one case, especially, in Cheboygan county.

In spite of the fact that no anthracnose was evident on the seed of the Idaho-grown Early Wonder beans, several well defined cases of this disease were observed on the growing plants during the season, both in Michigan and in New York. The following table shows the percentage of seeds affected with the blight and the anthracnose in average samples of Idaho-grown, California-grown, and Michigan-grown Early Wonder beans from the college plots of 1917:

TABLE 33.—DISEASES IN MICHIGAN-GROWN AND WESTERN-GROWN BEANS.

Number of seeds in sample.	Michigan-grown Early Wonder.		Idaho-grown Early Wonder.		California-grown Early Wonder.	
	Blight.	Anthracnose.	Blight.	Anthracnose.	Blight.	Anthracnose.
1000.....	40	24	30	4	30	8

California-grown Early Wonder Beans:

While the climate of Idaho is such as to practically inhibit the growth of either the bean anthracnose or bean blight organisms, the early frosts frequently destroy a large percentage of the crop in the bean growing districts. For this reason it was thought advisable to grow our seed under more favorable weather conditions. California was selected as the state with the most favorable climate. The Botany Department was unable to place beans for growing under contract in California, because the usual acreage had all ready been taken up by seed firms.

Through the cooperation of the Hess Elevator Company, Akron, Michigan, one bushel of Early Wonder beans was sent by them to be grown at Lompoc, California. These beans were grown under contract by the Lompoc Produce and Real Estate Company.

One and one-half acres were planted with the bushel of beans. The crop from this seed was 86 bushels. These beans were then returned to Michigan for distribution to the bean growers.

A plat on the College farm 60 feet wide and 200 feet long was planted to

this seed. These beans germinated well; the seedlings came up rapidly and evenly and produced an excellent stand of beans. These beans ripened about two weeks before either the Idaho-grown or Michigan-grown Early Wonder beans. The yield from this plat was 3.7 bushels or at the rate of 13.9 bushels to the acre. It was noticeable that the beans from the California-grown Early Wonder seed were more free from anthracnose and blight than any of the others grown in adjoining plats. The beans from this crop are uniform in size, shape and color, conforming to the standard commercial Michigan pea bean.

It is noteworthy that the yield of field pea beans due to unfavorable weather was less than 8 bushels per acre.

VALUE OF RENOVATION OF SEED BEANS.

With the enormous acreage planted to beans in this state, the securing of clean seed is of prime importance. Weather conditions during the growing season are such that in ordinary years both the anthracnose and blight flourish, in spite of the care exercised by the growers in obtaining good commercial seed. Each year there is an intensive, state-wide search for seed grown in localities having a minimum of rainfall, and consequently showing a low pickage of diseased beans. This was well exemplified during the season of 1916, when it was next to impossible to find beans showing a pick of less than two pounds a bushel, from which to prepare seed stock. Had the season of 1916 been as favorable for the anthracnose disease as that of 1915, the Michigan bean industry would have suffered an immense curtailment in 1917. As it was beans were so scarce that it was impossible to obtain good seed during the latter part of June.

Any measure which will provide a constant source of clean seed is of the greatest value to the bean industry in this state. The growing of Michigan beans for one or even two seasons in some western state where the climatic conditions are extremely unfavorable to the diseases, presents the best means of combating bean diseases in this state, at least until a disease-resistant variety of beans can be obtained.

The growing of beans in Idaho is rendered more or less uncertain because of the early frosts; in California bean blight is far more serious than in Idaho. With careful selection of seed for sending west, and the proper location, planting and cultivation of the crop, excellent results should be obtained from growing beans in lower California.

This method of obtaining clean seed on a large scale, should recommend itself to both the growers and jobbers. With a comparatively small expenditure the growers' or jobbers' associations could establish warehouses in a desirable locality in either Idaho or California and grow under contract each year enough beans to insure a fair crop in Michigan.

SUMMARY.

1. Bean anthracnose and bean blight are widespread and serious diseases in Michigan. Moreover, they occur in practically every state where beans are grown on a commercial scale.

2. Both diseases are carried to the field in or on the seed, and affect all parts of the plant above ground.

3. These diseases decrease the yield and cause a loss of the harvested crop. This loss is due to the unsalableness of the disease-discolored beans.

4. The pathogenes are easily carried from one part of the plant to another in drops of water. Cultivating when the plants are wet with dew or rain will spread these diseases.

5. The thermal death-point of spores of *Colletotrichum lindemuthianum* lies between 45°-48° C. Old mycelium will grow well after being exposed for 10 minutes in liquid culture to a temperature of 65° C.

6. While both organisms are dependent upon wet weather conditions for their initial development, *Bacterium phaseoli* causes serious damage during a dry season. The growth of *Colletotrichum lindemuthianum* is greatly checked during a dry season.

7. *Colletotrichum lindemuthianum* and *Bacterium phaseoli* live over winter in the soil or on diseased bean trash in the soil. Neither organism survives passage through the alimentary tract of cattle. They may be carried to the field on diseased bean trash in manure.

8. Seed treatments with chemical solutions and wet and dry heat have failed to control these diseases.

9. Spraying should, to a great extent, control the anthracnose and blight, if the spray material is applied thoroughly and the applications are made soon enough. The first application should be made while the cotyledons are still on the seedlings.

10. These diseases can be greatly reduced through the use of clean seed. Such seed can best be secured by pod selection or from Michigan beans grown one year in California or Idaho.

11. *Native western beans can not be successfully grown in Michigan.*

12. By growing Michigan seed beans in Idaho or California, Michigan can secure clean seed each year, regardless of local weather conditions during the previous season. Such seed, if planted consistently, as a general practice in the state, would reduce the losses due to these bean diseases to a negligible amount.

RECOMMENDATIONS.

The results of our work on the control of the bean anthracnose and bean blight show the ineffectiveness of seed treatments. It is still rather an open question as to whether or not spraying can be done efficiently and profitably. Certainly under the existing practice of planting beans by drill, spraying cannot be done as thoroughly as it could be done if the beans were planted in check-rows or hills.

The use of clean seed then presents the safest and surest control measure for these diseases. The cleanest seed can be secured by the method of Pod Selection (Page 38). Seed better than the average quality bought at local elevators can be obtained by practicing field selection and carefully hand-picking it.

We recommend the growing of early maturing Michigan seed beans of a known strain in some western state, where bean diseases are rare or absent, and the planting of such beans each year in this state. If such a scheme were followed, and individual growers planted only this clean seed, it would be a matter of only a short time until the losses due to bean diseases would be a negligible quantity. Eventually the stocks of beans in Michigan might become free from anthracnose to such an extent that sending the seed west for renovation could be abandoned.

The growing of Michigan seed beans in Idaho or California is not to be recommended for individual growers. Local growers' associations, however, could profitably take up the growing of the seed for their own members.

Cooperative or independent elevators are in much better position to carry on such a business than organizations of growers, owing to their familiarity with such work and larger capital.

It would be well in a year when the dry weather here resulted in a stock of seed beans free from anthracnose to reserve some of this seed for planting two years hence in case the intervening year was wet and the resulting crop diseased.

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